AN OPTIMAL RESOURCE ALLOCATION MODEL FOR CORPORATE TACTICAL PLANNING

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VOLUME CONTAINS CLEAR OVERLAYS

OVERLAYS HAVE BEEN SCANNED SEPERATELY AND THEN AGAIN OVER THE RELEVANT PAGE

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S T R U C T U R E   O F   D I S S E R T A T I O N

SUMMARY

My thesis is about planning the optimum allocation of resources in the medium term. It views the problem at the level in the organisation at which there are quantifiable interactions between the demands for and supplies of resources which ought to be resolved simultaneously. The research was empirical, my thesis is descriptive and normative.

I suggest a new conceptual approach to the planning of resource allocation which both fills a gap in the literature on 'how' to plan and provides one solution to some basic problems in the current practice of planning. The basic problems were of concept and execution.

Of concept because the planning process did not recognise that operational data may be inappropriate for tactical planning, that resources cannot be allocated rationally by consolidating and pruning functional plans and finally that many demands for and supplies of resources must be considered simultaneously.

Of execution because the method of processing the data was inadequate for the task, in that the technique was trial and error, the criterion was not financial and the means was manual.

In consequence, the plans from the old planning system were unachievable, inconsistent and non-optimal. Moreover, those responsible for the performance of the company had no effective control over the allocation of resources.

Besides a new conceptual approach, I suggest the use of a corporate optimal resource allocation model, discuss its construction and illustrate its use.

The empirical study concerned an engineering company in the medium to light category. The normative aspect maintains that the approach is valid at least for companies with a similar technology and perhaps to other industries which satisfy certain conditions. These technologies and conditions are defined in the main body of the dissertation.

MODELS FOR

CORPORATE TACTICAL PLANNING

IN MANUFACTURING

CONTENTS

1. INTRODUCTION

Despite all the attention corporate planning is receiving from many directions, there is one aspect which has been conspicuously neglected, namely, how a company should organise the process of allocating resources.

This neglect is not immediately apparent from a keyword search through the existing literature based on the title of this dissertation. In general, writings will be found to fall into one or two of three categories: theory, application, practice. The distinction between the last two is more blurred than the others. Applications usually refer to classes of problems such as trans-shipment, travelling salesman and blending. In contrast, practice refers to a particular instance within a class.

Relevant literature comes from at least four areas of study: finance, linear programming (L.P.), planning, production. Insofar as these are subsets of wider areas, a case could be made for expanding the boundaries still further. But these four will do for the present.

In the attempt to apply existing theory to a practical situation, I discovered that in all four areas the literature did not adequately cover the ground. The deficiences were evident not so much in each area on its own, as in their joint application to resource allocation at Massey-Ferguson (M-F). The man deficiencies related to applications of existing theory to a class of problems of which planning at M-F is one instance.

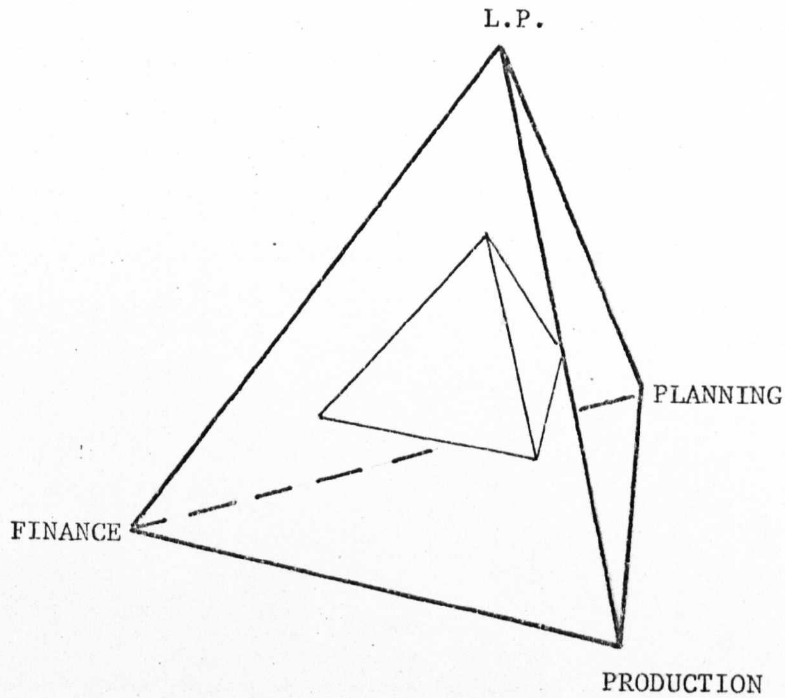
The approach I developed took the form of an optimal resource allocation model which had a number of interesting and perhaps novel features. It was successfully demonstrated and accepted at two levels in the organisation. It was accepted by top management who wanted a tool to help with the broad policy issues arising in the agricultural and industrial machinery business: product line, sourcing, capacity, etc.; and by line managers responsible for developing tactical plans over a one or two year horizon.

I suggest that M-F is sufficiently typical of manufacturing industry for the omissions in the literature to be of substance. The three schematics of Exhibit 1 attempt to summarise the position outlined so far.

The dissertation is divided into two main sections: the body and the appendices. The former is a resumé of the most important descriptive and normative aspects of the work. It summarises the previous work in the area and isolates the unresolved problems which are the subject of this dissertation. It then presents the particular industrial situation for which a model was developed and applied in practice. Finally, it discusses the more general use of the approach and its limitations.

The appendices provide more detailed justification and evidence than is given in the body of the dissertation. Each appendix has been written, as far as possible, as a self-contained module, on the assumption that the reader has not necessarily read any of the other appendices. The penalty of this approach is a mild degree of repetition. The advantage is the possibility of skipping large amounts of material which might be redundant for a particular reader.

Exhibit 1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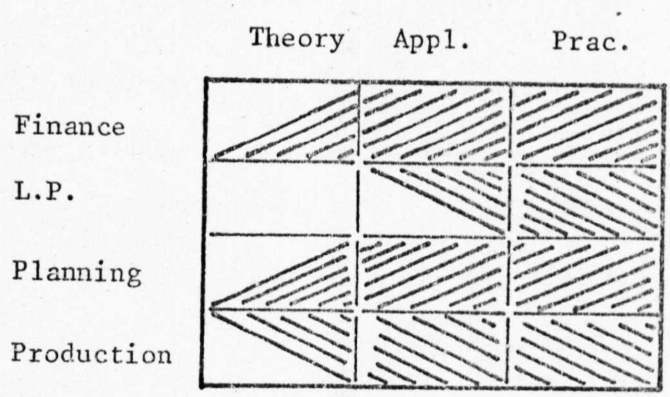
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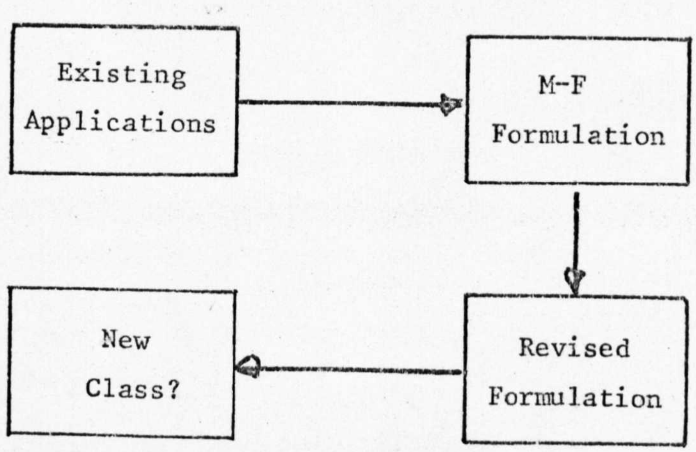

Existing Applications
M-F Formulation
Revised Formulation
New Class?

Before reviewing the literature it might be helpful to mention the main characteristics of the approach as they relate to each of the four main areas of study referred to above.

- Finance: the estimates for and results of capital budgeting procedures are an integral part of other planning activities; the medium for financial planning is not functional budgets, in the first instance; in some cases cost accounting data for direct variable costs overstate, in others, understate, the marginal cost of production.
- L.P.: the model concerns m products, n departments and is dynamic; it includes the main demands for and supplies of resources; manpower, overtime and sales are all variables; there are costs and limits on the rates of change of manpower; the amount of overtime available is related to the number of men on the regular payroll; both labour loading and machine loading are included; the objective is maximisation; the model is capable of analysing a wide range of policy issues.
- Planning: it is difficult, if not impossible, to profit plan for interdependent variables using a sequential and iterative process; it is also difficult to profit plan when a majority of the company's resources are pre-empted by the activities of a function whose planning involves neither costs nor profits; functional budgets are not an appropriate vehicle for achieving initial consistency or eventual profitability.

- Production: the activities of production control influence (a) costs, (b) profits, (c) assets, (d) inventories, (e) capital expenditure plans; it is desirable that the planning concepts and processes explicitly recognise the pivotal role of production planning and its interdependence with other functions such as marketing, etc.

With this framework in mind, section 2 reviews the literature.

2. REVIEW OF RELEVANT LITERATURE

This section reviews the contribution of four books in some detail, other literature more briefly and finally isolates the gap between the literature and a few of the practical issues at M-F of planning resource allocation.

The four books were chosen because each author is well-known and represents a different approach to the topic. The motive is to show how they were aware of the problems of corporate planning which still remained to be solved and to indicate the extent to which this project is indebted to their earlier contributions.

The four authors are Solomon, Bower, Ackoff and Driebeek. To summarise: in a limited way I share Mao's view that Solomon appears confused about the nature of the resource allocation process, however, Solomon does initially discuss the problem in general terms before concentrating on the specific issues of certain aspects of financial management. Bower's book is a behavioural study, in the last chapter he points out the need for an innovation to make possible the tasks he prescribes for the 'integrators'. Ackoff specifically excludes the question of how to plan, nevertheless, in the chapter on Resource Planning, his comments do not represent an entirely accurate description of either the problems or possible approaches. And finally, Driebeek, in chapter 14, has a heading 'Total Corporate Model', but then describes a total corporate production planning model.

2.1. Ezra Solomon - The Theory of Financial Management

One view of corporate planning is that it is synonymous with corporate financial planning. Or, if the author has a financial background, vice versa. Ezra Solomon in his book 'The Theory of Financial Management' probably epitomizes the latter approach.

However, he appears to be ambivalent about the scope of financial planning. Perhaps it is not what financial management is to achieve, but how it is to achieve it, that causes the inconsistencies.

On the one hand he suggests: a centralised process for analysing current operations and for making decisions about the acquisition, deployment and disposal of resources; a system for analysing all demands for and supplies of resources and for matching them in an optimal fashion.

This gives the impression of nothing less than a corporate system for the optimal allocation of resources.

On the other hand, he says that financial management should only be concerned with decisions involving changes in the use of funds, with the acquisition and destruction of assets.

This looks like the traditional narrow approach of capital budgeting.

Even his short paragraph on the distinction between profit planning and financial management - the former is a function of lower, the latter of top, management - does not resolve the conflict. The duties of financial management at one point specifically include the allocation of resources to and the continuing analysis of current operations, and elsewhere exclude it.

I back his intuition against his reservations. The capital budget should not be drawn up independently of plans for the other resources: the development costs of a new project are manpower costs; the operation of new plant requires direct labour; the resources absorbed by the future operation of the current facilities making the existing products have a decisive influence on both the financial implications and technical feasibility of new investment. And finally, apart from deriving mutually dependent plans simultaneously, it should be possible to analyse alternative courses of action and optimally match demands for and supplies of resources.

There is substantial agreement on what should be achieved, the problem is how to achieve it.

2.2. J. L. Bower - Managing the Resource Allocation Process

Bower's book sounds as if it covers the same ground as this dissertation. In fact his work (a) is based on a decentralised company, (b) is behaviourally oriented, and (c) is only concerned with new investment which changes the future course of the company. Despite these important differences in emphasis, the present study covers the systems and procedural side of problems he discusses as a behaviouralist.

Starting with the literature on capital budgeting, he says that its recommendations, although theoretically correct for a class of decisions, are in practice irrelevant because the class is extinct.

He develops a new conceptual framework for thinking about the process of allocating resources, which he defines as new investment decisions. The framework has three phases: corporate, integrating and initiating; and four processes: definition, impetus, structural context and measurement.

Bower says that the process of changing the product/market/ facilities posture of a company consists of two parts, (a) routine and (b) critical. Routine change is the continual use of assets and generation of profits which result from the activities of the ongoing business. He ignores routine change.

For critical change he defines two components, (a) the business planning process, and (b) the investment process. The former corresponds to strategic planning (choice of markets and product objectives) and the latter to tactical planning (commitment of resources).

Critical change is achieved within the new framework of phases and process.

His definition of the area of study precludes an analysis of the important relationship between planning over different time horizons and the initiation of investment projects. He suggests the picture of a facility-oriented initiator perceiving a discrepancy which the reward and punishment system motivates him to overcome.

As a development of this valuable approach I would suggest firstly that planning is not just a step down sequence from strategic to tactical. Secondly, that current operations are an important component of planning the allocation of resources. And thirdly, that medium term planning (tactical) plays a distinctive role in the initiation of projects and their subsequent analysis. The fact remains that strategic planning often starts from an analysis of the strengths and weaknesses of the company, one component of which is identified when the present course of the company is extrapolated into the future, i.e. it starts from tactical planning, which has as its base the current operations (Bower's excluded routine change). Moreover, it is important, before committing resources to new projects, to test out the tactical consequences of new projects when combined with the future plans of current operations.

Bower mentions these problems, although expressing them in different terms, when talking about the importance of the integrating phase in the process of impetus. His integrator is sitting in-between corporate staff and the initiator, transforming strategic measures into financial ones; correcting and qualifying potentially misleading financial summaries and selecting projects for submission to corporate.

Additionally, the integrator must make trade-offs between short-run pressures for current performance and long-run pressures for future earnings.

This is a very interesting role. The integrator second-quesses, makes trade-offs and selects, in the knowledge that the appropriations committee acts as a go/no go filter, and has never turned down a project.

The important decisions are therefore made by the integrator, provided he has done his political homework.

Having posed the problem so succinctly and having discussed the demanding functions assigned to the integrator, Bower has these concluding remarks to make on the subject:

> 'It would seem that the role of second source is too important for the cited drawbacks to prevail. Rather they must be overcome with managerial skills, perhaps with some yet-to-be conceived organizational innovation'.

This dissertation is about one innovation which might help to make possible the role of the integrator. Although my work concerned a centralised manufacturing company, the integrator between a decentralised division and head-office has much the same problem as a corporate planning department in a centralised company.

Whereas Bower's work ably tackled the behavioural problems of the resource allocation process, mine is concerned with developments in procedures, concepts and techniques which make possible the implementation of his prescription to certain types of industry.

2.3. R. L. Ackoff - A Concept of Corporate Planning

This book is of immediate interest, if for no other reason than the coincidence of title, author and discipline. Despite a disclaimer in the introduction that 'I have not produced a handbook, a how to do it book', there is a chapter on Resource Planning.

He identifies four types of resource (a) money, (b) facilities and equipment, (c) materials, supplies and services, and (d) personnel. The first three receive very little attention because 'Currently available techniques and knowledge enable us to plan reasonably well for three of the four types of resource: personnel planning is the least well developed'; the last receives the bulk of his attention.

Ackoff does discuss the first three briefly and in general terms. In so doing, he makes some suggestions which would have been conspicuously inappropriate for M-F and fails to make others of crucial importance to a viable system for resource planning.

In the first place, while advocating the use of a financial model, he says the existing accounting system is suitable; if manual, it should be computerised. This appears to assume that a system for collecting data is necessarily suitable for predicting data.

Secondly, the planning of each of the resources is discussed separately without any suggestion that they might be mutually dependent: for instance that the financial plan contains summaries of materials and manpower planning.

Perhaps these omissions are not so much oversights as issues tangential to the main theme of the book. Nevertheless, it could be argued that a slightly less sweeping generalisation about existing techniques and knowledge might have led to a little more honesty about the difficulties which still remained and some of the pitfalls awaiting the unwary.

The normative aspect of this dissertation takes a fresh look at how resource planning can be accomplished - an application of existing techniques, an extension of existing knowledge.

2.4. Driebeek - Applied Linear Programming

A book with such a title holds out considerable promise of having a chapter on corporate planning - the allocation of scarce resources to competing ends subject to specific constraints in such a way as to maximise the value of an objective.

One example cited by Driebeek is called a 'Total Corporate Model'. The company was a multi-product, multi-plant manufacturer of containers. The purpose of the model was to computerise the production planning operation, as the manual system was unable to cope. He describes a linear programming formulation for cost-minimisation and production smoothing.

Potentially Driebeek had a corporate resource allocation model, but the chapter gives no hint that he appreciated the fact or how the model would have to be adapted for this purpose. It was conceived in terms of and used as a production planning model.

Under the heading of sensitivity, Driebeek does mention that they managed to use the model to help decide on the location of a new plant, but he does not suggest that he developed the basis for a total resource allocation model capable of helping management decisions to acquire, deploy and dispose of company resources.

A total resource allocation model would probably have meant a different formulation, but he was surely right in suggesting that the heart of a corporate model of a manufacturing company consists of a model of the manufacturing process.

His last paragraph confirms the bias in the conception, construction and use of the model, 'The production planning personnel had cooperated extensively and they readily accepted the development of a total corporate production planning model'.

2.5. The Gap Defined

Perhaps the simplest method of extending the discussion to define more closely the facets of resource allocation in manufacturing not adequately covered by the literature is to take each of the four areas in turn.

2.5.1. Finance

As mentioned in section 1, there are three aspects of immediate interest: capital budgeting, corporate financial planning and cost accounting.

- Capital Budgeting. The three aspects of this wide subject are: how are new projects initiated?, how are the cost estimates developed?, how are the benefits measured?. Bower criticises capital budgeting literature for being theoretically correct and practically useless. In general, apart from the usual comment in the literature that estimates should be incremental, the emphasis is more on the techniques of appraisal than the process of generating the proposals. Quirin's book is an example of this approach. In chapter 2 he discusses project generation, evaluation and selection. Of both types of capital expenditure decision he says 'it is probable that a large proportion of proposals originate in a rather haphazard fashion'. This is fine as description, but one expects some normative guidance. There is little about the contribution that integrated planning could make to the initiation of both types of expenditure proposal. In chapter 4 Quirin talks about the correct estimates, but omits to mention the problems of generating incremental costs and benefits.

Research Report 43 of the National Association of Accountants does discuss the relationship between capital budgeting and long-range and annual planning. While stressing the need for integrated and comprehensive planning, there is little about the problems of achieving it and how these might be overcome, apart from advocating the project approach.

To give the last word to Bower: the problems are now with selection and estimation, not evaluation.

- Corporate Financial Planning. Solomon is an able exponent of this subject and the comments in the earlier part of the present section do not need reiteration. There are two additional points: firstly, financial planning is not well done if it picks up the story after the estimates come to head office, and secondly, budgets are a suitable expression of the financial implications of tactical plans, they are neither a substitute for tactical plans, nor a good vehicle for tactical planning.

- Cost Accounting. The shortcomings here are nearer those of concept than application. The point is easily made: present developments in industrial relations, the power of the unions, etc., make the assumptions behind the definition of direct variable costs increasingly obsolete. Seldom is it true that the direct variable cost of a product, as usually defined, corresponds to its marginal cost. Moreover, the marginal cost is as likely to be below direct variable cost as above it. Neither Horngren, Shillinglaw nor Brown and Owler seem to recognise this. For example, Shillinglaw suggests that incremental costs are direct variable costs plus certain decision costs which can be attributed to a particular policy decision.

  The reason for marginal costs almost never corresponding to direct variable costs (quite apart from the usual variances between actual and standard costs) is that decisions about products and decisions about direct labour are not necessarily linked in the manner assumed by direct variable costs. The direct labour required by a production programme is only in part influenced by the direct labour content of the product. Other influences are industrial relations policy on hiring and firing, overtime, short-time, and so on. One method of getting at incremental costs is to build a model containing all these factors and evaluate the consequences from the results. On one occasion marginal cost will be less than direct variable cost, on another it will be greater by the addition of premiums and the hiring costs of additional men.

2.5.2. Linear Programming

The class of problems referred to in the literature as production smoothing was appropriate neither to the task of production control at M-F nor the wider issue of the relationship between production control and corporate planning.

The theory of L.P. and its extensions as developed by Dantzig and explained by such authors as Hillier & Lieberman and Gass was capable of describing the situation at M-F with acceptable precision.

The literature on applications and practice appears to miss several important characteristics of the problem.

The characteristics of a job-shop are well described in an article by Elmaghraby, but he goes on to develop an approach to scheduling parts instead of products. In a book he discusses an L.P. formulation for production and inventory systems. It is a single product, single department problem, and includes overtime working, costs and limits on changes in capacity, as well as inventory. However, simply expanding the model by the addition of more products and more departments would not be appropriate for M-F for several reasons. First, he uses the separate factory approach to capacity (x = hours of regular time production, y = hours of overtime production); this works for the simple case but not for a more complex model. Secondly, he defined recursive, cumulative relationships going through the model from the last period to the first, which makes the model difficult to maintain. Thirdly, he does not explicitly mention the problem of the capacity of existing facilities.

Neither Teichroew nor Hanssmann get as far as Elmaghraby. Their formulations are more general and of less relevance.

Going on to a different aspect of the problem, Wagner mentions the difficulty of obtaining relevant data but has no specific suggestions about either cost or production data.

None of the authors on the subject mentioned the class of problems in which all the following properties are of interest:

- production smoothing is part of corporate planning and resource allocation;
- planned actual sales are variables;

- the objective is maximisation;
- there are n products in j departments with different constants for each product/department combination;
- overtime availability is linked to the number of men assigned to the regular payroll (the latter is therefore a variable);
- there are costs and limits on the rate of change of manpower;
- labour loading and machine loading are included;
- separate tranches of capacity are not treated as separate factories (X_{ij} = amount of product i made in tranche j).

Apart from the first three and the last points, the others are mentioned by a number of authors in different combinations. However, this is an instance of the total problem being more complex than the sum of its parts.

A complete description of the formulation is contained in Appendix 4.

2.5.3. Planning

This subject has spawned a vast literature. Steiner's book about the theory and practice of planning is probably one of the most comprehensive. It covers every aspect from strategic planning to short-term operational planning. While passing through tactical planning he equates it with budgeting and emphasises the need for internally generated data, especially accounting data. In the chapter on techniques he mentions

L.P. On the whole, those parts of the book devoted to tactical planning are better on describing the framework than the substance; although even some parts of the framework seem a bit shaky. Many practical problems appear to be inadequately discussed (perhaps this is unfair, the book already has 800 pages):

- consistency;
- generating corporate plans from functional budgets;
- profit planning by consolidating and reviewing functional plans;
- profit planning when a significant proportion of company resources are allocated as a consequence of functional plans which are neither cost-nor profit-oriented;
- sequential and iterative planning processes;
- trade-offs between interdependent variables;
- 'what if' of policy formulation.

Perhaps the explanation is that it is easier to generalise about the concepts of planning than the practice. But, on the other hand, even his concepts of tactical planning do appear to gloss over some of the practical difficulties.

Almost all the books were better on strategy than tactics. Another example is Argenti. In his five step practical guide, the last step was tactical planning. The main suggestion was that the sole responsibility for each part of the plan be given to one man, that he be given the specifications for the plan and be required to make progress reports. This is perfectly reasonable advice, but one is left with the feeling that there is something more that a practical guide should say.

Ewing, in a book on practice, is primarily concerned with the concept of practice.

Steiner & Cannon again emphasise strategic planning. Their comments on tactical planning regard the latter as activities of sub-units in the pursuit of strategic objectives. There is little discussion of the problems of generating tactical plans or of how to modify them if they are not consistent with strategic goals.

Newman & Logan mention what information is needed for tactical planning, and omit to suggest how it might be processed, and how the results could be used. They also imply that the medium for tactical planning is functional budgets.

To generalise, it could be said that the practice of tactical planning fares badly in the literature. In part the concepts are inadequate for the tasks, which implies that the applications of the concepts probably inherit the latters' deficiencies and may have a few of their own.

2.5.4. Production

In general, production literature views production control as an activity separate from the other activities of the company. The objective is to minimise costs or fluctuations in labour activity: the sales forecast is an exogenous variable: capital expenditure should be approved to enable capacity to match sales, and so on.

Burbidge has a good introductory text on the subject, with an excellent glossary of terms. In the chapter on production programming he talks about planning boards, and the need for an optimum balance between production and sales. There is no mention of how this balance can be achieved, merely examples of the consequences of imbalance. Integration of sales and production plans are to be achieved via budgetary control. In an important paragraph he does say that decisions taken in production control influence: capacity and output, costs, fixed assets, stocks. There is no mention of profits, and elaboration takes one-and-a-half pages. L.P. is mentioned in chapter 16.

Moore emphasises the importance of the link between production and sales but says nothing about deriving and optimizing joint plans.

Bowman & Fetter discuss capacity allocation, production scheduling and L.P. However, the objective is to establish general relevance rather than to be exhaustive.

Magee has two chapters, 7 and 9, of slight relevance, but both are too general to come to grips with practical complications.

Buffa's book of readings is divided into a discussion of general problems and examples of applications. Neither covers the class of problems of which either production control or corporate planning at M-F is a subset.

The lack of relevance of the existing literature on production can be classified under two headings:

- the failure to describe a model to fit the production processes at M-F;
- the failure to emphasise the role of production planning and resource allocation, and the way this should modify the concept and process of planning.

The expansion of these two corresponds to that under L.P. in 2.5.2., and so will not be repeated.

3. THE CORPORATE PLANNING PROBLEM

Why does the 'how' of planning the allocation of resources cause so many difficulties? This is the topic of the present section. For a more detailed treatment the reader should turn to Appendices 1 and 2.

One of the answers, I believe, is a failure in diagnosis, in that top management does not perceive the underlying causes which generate a continual stream of diverse decision-making problems. These problems have in common the need for reliable quantitative data about the likely internal consequences of alternative courses of action.

Bower states the issues very well. On the one hand, any competent executive can make the figures tell whatever story he wants. On the other hand, top executives wish to control the future course of the company by allocating resources to those projects which are most likely to further the company's interests. Bower goes on to say that the result of most planning/budgeting systems is to give top management information they are least able to handle. Bower's solution is neither to change the role of nor the information going to top management, but instead to place an integrator between top management and the divisions who second-guesses financial summaries of projects, corrects misleading figures, examines alternatives and ranks projects. Bower finishes his book with the question 'How is the integrator to perform this task?'.

I think Bower has identified what I would call 'The Corporate Planning Problem'.

Without going into all the details, the problem divides into two parts. The first concerns errors, and the second omissions.

3.1. The Errors

In general, the errors are due to a faulty concept of tactical planning, incorrect data and an inadequate method of processing the data. The evidence that something is wrong with the current practice of planning is the frequency with which consolidated functional plans are inconsistent, unachievable, non-optimal and unacceptable.

- Concept - many planning systems use a sequential process for drawing up functional plans which are then sent to head office for consolidation. The consequence of this process is that costs and profits, instead of being a criterion of choice between alternatives, are the results of decisions made on non-financial criteria. In other words, the major decisions affecting the allocation of resources are made without any awareness of the financial consequences. The attempt to improve the final profit figure, either by pruning the consolidated plans or by recycling the planning process with some fresh guidelines, does not go to the heart of the problem. The point is that all interdependent demands for and supplies of resources must be planned simultaneously, i.e. the financial plan is not unrelated to either the manpower plan or facilities plan, as Ackoff would appear to have us believe.

- Data - the second difficulty with attempting to allocate resources on the basis of plans submitted by the functions is that not only do the functional plans reflect functional objectives (and it is sometimes hard to discover how these have biased the figures), but also functional data is often inappropriate for corporate tactical planning. The reason for this is that functional data tends to be operationally oriented; whereas in the broader perspectives of tactical planning, new trade-offs are possible, different options exist: for instance, the standard costs produced by the costing section at M-F are based on assumptions which are not valid for tactical planning. Appendix 7 gives details of errors in functional data.

- Processing - besides the need for the simultaneous assignment of values to all interdependent decision variables; informed, rational decision-making requires the capabilities of evaluating the consequences of a variety of different policies and of combining the demands for and supplies of resources in such a way as to maximise profits. The requirement for simultaneous assignment and evaluation of options rule out manual calculations, and for maximisation rules out trial and error; only an optimisation technique and a computer will suffice.

3.2. The Omissions

Apart from having reservations about the utility of the figures produced by the usual planning system, for the reasons mentioned in 3.1., there are a number of desirable pieces of information which there is often no attempt to provide:

- Sensitivity analysis - this is a well-known procedure for exploring the consequences of specific changes in the value of selected input variables. It is one method of allowing for risk without constructing a stochastic model. To perform this type of analysis it must be possible to run through the planning cycle a number of times. Obviously, this is out of the question with a manual system which takes 6-9 months to generate a single set of plans.
- Vulnerability analysis - often confused with sensitivity analysis, it is in fact different in two important respects. In the first place, vulnerability analysis refers to the systematic exploration of the consequences of changes in the input costs and parameters and output activity values of all decision variables. Secondly, it does not require rerunning the planning system with new input values, instead it is an analytic procedure carried out after the optimal allocation of resources has been determined. The effect of vulnerability analysis is to automatically identify the variables having a key influence on profits.

- Profit improvement - not only should a planning system be capable of evaluating the consequences of proposed action programmes (new management action), but also it should be capable of pinpointing those areas having the greatest potential for profit improvement. It may be something easy to remedy, such as a different finished machines inventory policy; or it may be virtually impossible, for instance, a restrictive practice by the trade unions. But even in the latter case, management is aware of how much it is worth paying to buy-out the restrictive practice.
- Effects of uncertainty - one of the arguments frequently used to discredit the use of advanced planning techniques is that in the medium term the error in the estimates of the basic data entirely swamp any significance the results might otherwise have had. This attitude would betray less prejudice if it were phrased as a question rather than as a conclusion, e.g. is it possible for the planning system to identify the error in each estimate which can be tolerated without the basic allocation of resources being affected?

Before closing this section of the dissertation it is worth reiterating that the approach to planning which is initially focused either on individual functional plans (marketing, production control, etc.), or on individual resource planning (finance, manpower, etc.) is inappropriate when decision variables are interdependent.

4. A POSSIBLE SOLUTION

The discussion of the previous three sections can be used as a specification for a planning system. There are four main strands to the solution of the corporate planning problem developed for the situation at M-F. Each is necessary, and, by itself, none sufficient. The four strands are: modified conceptual approach, the computer, linear programming and post-optimal procedures. The problems, and the contribution each strand makes to their solution, are illustrated in Exhibit 2 and discussed more fully in Appendix 3.

The fact that there are four strands to the solution and that each is necessary is evidence, perhaps, that this study is more than just another application of L.P. If so, the reason is that the study was problem-oriented instead of being either technique or solution-oriented.

4.1. The Revised Concept

It was necessary to revise the conceptual approach to planning at M-F because the old was incapable of accommodating the conflicting requirements of human behaviour, the maximisation of sustainable growth and the complexity of planning in a manufacturing company. The behaviouralists very reasonably assert that motivation, commitment and the reward and punishment system all require that the individual manager be associated with drawing up his own plans and setting his own goals. Those concerned with profits and efficiency prescribe the centralisation of control over

Exhibit 2

THE CORPORATE PLANNING PROBLEM AND SOLUTIONS

PROBLEMS		SOLUTIONS			
		Concept	Computer	L.P.	Post-Opt.
ERRORS	acceptable	X		X	
	achievable	X			
	consistent	X	X		
	optimal	X		X	
OMISSIONS	profit impr.				X
	sensitivity		X		
	uncertainty				X
	vulnerability				X
	what-if		X		

the resource allocation process because it is important to them that the company's interests prevail over those of a function or individual. Finally, a pragmatist, understandably wary of the pitfalls of management information systems, would want assurance that centralisation, and computerisation, would not involve the creation and maintenance of a large data base and computer model, both of which would probably be inflexible, expensive and rapidly obsolete.

A schematic of the revised conceptual approach is shown in Exhibit 3 and described in more detail in Appendix 3. Briefly, the more important features are:

- corporate planners specify the unresolved policy issues and the data (not plans) to be submitted by the functions;
- the functions submit data for the planning base and for the policy issues;
- the operational data is corrected for tactical planning purposes;
- the corrected data is input to a corporate optimal resource allocation model which contains as decision variables all interdependent demands for and supplies of resources;
- the outstanding policy options (product line, manpower, facilities, etc.) are tried out on the model and decisions taken;
- the decisions are embodied in planning guidelines, setting out the pattern of resource allocation and specifying limits

Exhibit 3

A NEW PLANNING CONCEPT

Targets and Guidelines ↓	From Corporate to Functions
Submit Data ↓	From Functions to Corporate
Correct Data ↓	Corporate
Run Model ↓	Corporate
Option Anal. ↓	Corporate + Functions
Policy Decisions ↓	Corporate + Functions
Pattern of Resource Allocation ↓	From Corporate to Functions
Submit Detailed Plans ↓	From Functions to Corporate
Consolidate & Approve	Corporate

for the values of variables (e.g. decision costs) not included in the model, and sent to the functions;

- the functions draw up their detailed plans within the limits of the pattern of resource allocation established by the corporate planning department and submit their functional budgets;
- should the final consolidated plans underperform the targets (a function originally misjudged the impact of a policy issue), the process is fast enough to permit recycling from the first stage, although it might not be necessary to go back that far.

This scheme has a number of advantages:

- Both sales and production capacity are treated as variables, which of course is true in the medium term, but represents an unusual L.P. formulation.
- The functions are represented at the stage when policy decisions are made. In this way they are actively involved in the debate about the rational allocation of resources.
- The final plans are more likely to be consistent, achievable and optimal.
- There are fewer surprises from the final consolidation of the plans, i.e. they are more acceptable, as most problems about the gap between the president's profit target and the company's profit potential should have been largely resolved at the fourth, fifth and sixth stages.

. The usual farce or game, depending on one's view, associated with the efforts of corporate planners to unearth hidden profit potential is no longer so necessary.

4.2. The Computer

The computer is directly responsible for the solution of three problems and is party to the contributions of L.P. and Post-Optimal Analysis, although this is not shown on the diagram, insofar as neither of the latter two would be possible without it.

The problems to which it contributes most of the solutions are: consistency, sensitivity and what-if. These need no explanation other than the fact that the processing speed of modern computers is measured in nanoseconds and that general purpose machines can handle large amounts of input and output.

4.3. Linear Programming

This is a more contentious part of the approach than either of those already mentioned. There are people who prefer a manual planning system to a computerised one, but many more who advocate simulation instead of L.P. There are several factors to be weighed: the nature of production technology, management's needs for planning information, its ability to assimilate new techniques and adapt to change, and its attitude to risk. The last point is important. The chances of not constructing a good L.P. are higher than of not building a good budget compiler. The model developed for M-F went through a number of stages of refinement, which stopped when its performance was acceptable to management. The criterion was that there should be a useful improvement over existing systems. Its formulation is described in Appendix 4, results in Appendix 5 and uses in 6. Obviously, further development is still possible, and this topic is taken up again in section 7 of the body of the dissertation.

Of the possible approaches to optimisation, those of Bellman and Holt et al, were not adopted for the usual reasons.

If the assumptions of L.P. can be met either directly or with the help of a few mathematical tricks, there are some advantages of using L.P. instead of simulation (budget compiler):

- good L.P. codes exist for most computers, so that building a model is a matter of formulating equations and collecting data; with a simulation model the program would have to be written as well;
- an L.P. model is inherently more flexible than a simulation model insofar as a change which involves reprogramming the latter only requires new input data for the former;
- the decision rule implicit in the objective function of an L.P. cannot be replicated in a simulation model without a prohibitive number of explicit decision rules and a large amount of temporary storage of intermediate results;

- the development costs of an L.P. model should be smaller than for a simulation model as there is no computer program to write and debug;
- similarly, the cost of maintenance and the vulnerability from staff turnover is lower for an L.P. than for a simulation model, provided the company is prepared to hire staff of the requisite calibre.

From most viewpoints: development, maintenance and results, depending on the company, an L.P. is preferable to a simulation model.

4.4. Post-Optimal Analysis

This is mentioned separately as not all L.P. codes have the facilitiy for performing post-optimal analyses. After an optimal solution has been obtained, a number of further questions may be asked about the particular optimum, e.g. about the vulnerability. The two procedures which provide the additional information are usually called Ranging and Parametrics. Both procedures operate on the objective function and the R.H.S. either separately or together. Ranging asks the question,'how far can the value of each variable move in either direction, while holding the value of all other variables constant, before the optimal solution changes?'. An extension of this problem would be to ask, 'what happens to the optimal solution when more than one coefficient moves over a specified range of values?'. This is parametric programming.

5. THE SCOPE OF THE PLANNING MODEL

The purpose now is to define more closely the sector of the planning spectrum for which the model was developed, and to introduce the company. Together these suggest the types of problems for which the model can be used. The company is mentioned first.

Massey-Ferguson U.K. produces farm equipment (F.E.) - tractors, combines, drills, etc. - and industrial construction machinery (I.C.M.) - tractors + diggers and loaders. It therefore comes under the heading of manufacturing industry. There are three manufacturing plants: one for tractors (Banner Lane, the largest tractor plant in the world), the second for farm equipment and industrial diggers and loaders (Barton Dock Road - B.D.R.), the third for combines (Kilmarnock). The last two plants, at times, make parts for each other and for the tractor plant. The project was centred on B.D.R. with the intention of establishing the viability of the revised approach to planning. The factory was run as a large job-shop; its basic production control and accounting data was good and records went back at least five years.

B.D.R. produced about 9 main line machines (products) and had 8 or 9 productive departments. The uncertainty over the number of products is caused by there being frequent changes to the product line and to sourcing. While that over the number of departments depends on how the assembly area and the machine shop are classified. In manufacturing industry it is not unusual for the plants to account for at least 70% of all resources: money, facilities, materials and personnel.

Top management, unhappy with the response of the planning system to their demands for information, thought it worthwhile to attempt to improve the planning process. Initially the focus was on decision costs, it then moved via production planning to resource allocation and tactical planning. The objective was to integrate and, if possible, optimise the joint plans of the different functions.

Exhibit 4 shows some of the components which can be used to specify a planning system. Associated with each component are two or three attributes which commonly describe more precisely the area of interest. Thus, the planning horizon is typically divided into three periods: the long term or strategic planning which concerns the nature of the business, the markets and so forth; the medium term or tactical planning is a statement of how the strategic objectives are to be achieved, the main decision variables are such things as production plans and manpower, the unit of time may be one month and the plan may look one, two or three years ahead; finally, there is short term or operational planning covering day to day affairs in the appropriate detail. One of the descriptions of each component is boxed to indicate the particular sphere of interest of the planning model which is the subject of this dissertation. In contrast, the ringed descriptions show the characteristics of the planning system to be improved.

5.1. Level

The primary focus is planning at the corporate level, where variable but limited resources are allocated to competing uses after (a)

Exhibit 4

DESCRIPTION OF PLANNING SYSTEM

COMPONENT	DESCRIPTION		
level	function	division	corporate
behaviour	satisficing	adaptivising	maximising
structure	decentralised	centralised	
horizon	short	medium	long
philosophy	bottom-up	mixture	top-down
processing	manual	computer	
techniques	trial & error	heuristic	optimisation
sequence	sequential	simultaneous	

exploring the trade-offs, (b) evaluating the consequences of alternative courses of action, and (c) ensuring that wherever possible the interests of the company can prevail over those of an individual function. This activity by the corporate planning department establishes the pattern of allocation of the company's resources. The pattern is embodied in a policy document sent to each function, and is the framework within which detailed functional plans and budgets are drawn up and submitted.

5.2. Behaviour

Much has been written about the theory of the firm and I have no wish to join the controversy. However, a planning model, if used, will tend to alter the manner in which behaviour is expressed in performance. Implementation is made easier if extensive education or change is not required on the part of the executive for initial understanding and use of the model. At first, while the new man/model interfaces are established, it ought to be possible for the manager to continue with many of his previous behaviour patterns: whether this is the bargaining between coalition members proposed by Cyert and March, or the process by which the integrator decides which project should receive backing and impetus, according to Bower. At M-F the model was accepted partly because no great change was required in the way management formulated ideas and questions. Answers coming back from the model were catalysts to new ideas.

The planning model I constructed accommodates management's idiosyncrasies by permitting two extreme modes of operation, as well as any variation in-between. The two modes correspond to two attitudes towards the value of any particular decision variable. On the one hand management may specify a particular policy towards an individual variable or class of variables. An example might be that reductions in manpower must be limited to natural wastage. Such a policy could result in a particular variable being given a specific value or a range of possible values. In both cases management has a definite view about the value or values which can be assigned to the variable in question. On the other hand, management is assumed to be indifferent to the values taken by the remaining variables, apart from the preference that these should tend to generate more profit rather than less. It is this flexibility which enables the model to initially accommodate and perhaps to subsequently modify management behaviour. The model is properly described as a maximisation model in that it assumes that where management is indifferent to the value of a variable, the value assigned to it should be consistent with higher profits (greater efficiency) rather than lower.

5.3. Structure

The dissertation relates to planning at the level in an organisation at which there are quantifiable interactions between the demands for and supplies of resources. In a centralised, undiversified company this corresponds to the activities of the corporate planning department. In a decentralised, highly diversified company, this approach would have more in common with the tasks of the divisional planner than the corporate staff. At M-F the most difficult and contentious problems often arose at the level in the organisation where the activities of one function (for instance) affected the actions of other functions, which in turn caused the original function to modify its initial proposals. It was this interdependence which made it imperative that (a) the values of the interdependent variables be determined simultaneously, (b) corporate plans should not be the result of consolidating and pruning functional plans, and (c) that the company objective should override functional objectives. Other companies in the same or different industries might well suffer from the same problems. Bower's descriptions of the resource allocation process in three divisions of an American company, and his invention of the integrator, confirm that M-F is not the only company to suffer in this way.

5.4. Horizon

Tactical planning is not only important because of the role it plays in profit planning, it also has a significant contribution to make to both operational and strategic planning.

In the former case it facilitates the replanning of the immediate future for such decisions as the optimal sales mix, the manpower policy, production scheduling. The replanning could be necessitated by the occurence of unplanned operational events, e.g. a strike or shortage of a bought-in component.

For the latter, the demands that strategic planning place on the capability for tactical planning are to (a) evaluate the tactical feasibility of strategic plans, for instance, a product line policy, and (b) to assist in the analysis of the strengths and weaknesses of the organisation by providing information on the current position, rate of change and direction of change, i.e. the need for extrapolation. Both of these are illustrated in Appendix 6 on using the model.

5.5. Philosophy

The proponents of both bottom-up and top-down planning would probably agree that some form of compromise is preferable to either extreme. The debate is not so much about which should be used to the exclusion of the other, as which should initiate the planning process. My own prescription is that (a) the functions submit data (not plans) to the corporate planning department, (b) the latter determines the optimal allocation of resources which is transmitted to the functions as planning guidelines, and (c) the functions draw up their detailed plans within this framework. This approach is designed to ensure that, as far as possible, the final plans are consistent, achievable, optimal and acceptable.

5.6. Processing

Corporate planners must choose a method of planning and a degree of aggregation which permits them to process the figures, maintain the data and evaluate the options in a manner consistent with the legitimate demands of top management for reliable, relevant, quantitative information. Except for the smallest companies, these objectives can only be met if the data base is maintained on and manipulated by a computer.

5.7. Techniques

Trial and error is not capable of providing the information required for the rational allocation of resources. A heuristic method is an improvement on trial and error but still falls short of the benefits of an optimisation technique such as linear programming (L.P.). L.P. has many advantages in its favour other than the mere discovery of the optimum: namely, (a) sensitivity analysis, (b) vulnerability analysis, (c) shadow or marginal pricing, and (d) parametric programming of either the objective function or the right hand side. As I show later, in Appendices 5 and 6, the benefits of a well constructed L.P. can far outweigh those of either staying with a manual system or using a corporate simulation model.

5.8. Sequence

This has already been touched on, but the point is worth emphasising if only for the reason that the practice of planning in the U.K. is still predominantly at the sequential stage. Sequential planning is the process by which plans go from marketing to production, on to costing, etc. Attempts to improve the final profit by recycling are totally inadequate for two reasons (a) the time taken to complete on cycle, and (b) the number of cycles necessary for management to get a feeling for the interactions between the decision variables. One solution is for the simultaneous assignment of values to all the interdependent decision variables.

5.9. The Existing Planning System

M-F uses a planning system called Integrated Planning and Control (I.P.C.). Its aims are that:

- planning should occur in the same units, responsibility groupings and expense categories as those in which they are recorded and controlled;
- a manager should have a say in setting a budget for which he will subsequently be held accountable;
- plans are consolidated and reviewed on their way to head office, but are not adjusted without the consent of the manager ultimately responsible for each item;
- the tasks of corporate staff, during the planning process, are to set goals, supply guidelines, give advice, consolidate, review and resolve conflict;
- the final plan should be demanding and achievable;
- the plan may only be revised with approval from head office.

The strength of the system is that it is theoretically analogous to a vine growing along a trellis, i.e. the plans evolve from the bottom of the organisation within a framework laid down by the president and his staff. Managers are intimately involved in generating the figures, and they are controlled against their own estimates.

The weaknesses become apparent when the plans are consolidated and reviewed. Inevitably, adjustments have to be made; sometimes the consolidated profit is so far short of the president's goal that nothing less than a complete replan will do. To allow for this contingency, there is a preliminary plan around March and April and the final plan is submitted towards the end of the fiscal year, September and October.

The mechanism by which these adjustments are made illustrates management's reservations about the accuracy of the figures and the manner in which they are derived.

If profits are too low, planned revenue can be increased by management action to:

. raise prices;
. increase sales volume;
. make favourable changes in mix.

For costs, action is restricted to decision costs, and here the directive may be to 'reduce travel expense by x%'.

If the proposed use of funds exceeds the sources, capital expenditure is cut back by the deletion or postponement of projects.

Most of these adjustments have repercussions elsewhere in the system. To take one example; cutting out a cost-saving investment could well imply a new production programme to evaluate the consequences of compensating changes in overtime and inventories.

To the extent that neither the initial plans nor subsequent revisions recognised the interconnectedness of variables, the planning system could be said to be arbitrary.

M-F's experience illustrates some of the inherent weaknesses of using functional budgets to generate corporate plans.

It was not the intention of the project to replace the I.P.C. system. Rather, the purpose was to plan in an optimal manner the resources associated with engineered costs (manpower, capacity, etc.), to include some elements of decision costs, which could be directly related to the variables generating engineered costs (if the situation were correctly modelled) and to provide management with reliable estimates of these independent variables on which to base their estimation of the remaining decision costs.

The importance of achieving these limited aims can be illustrated by some figures from the 1970 Annual Report:

- cost of goods sold represented 77% of all costs;
- cumulative investment in productive capacity was 70% of fixed assets (tooling is expensed);
- finished machines inventory was 28% of current assets;
- investment in future capacity accounted for nearly 50% of the use of funds.

6. ACCEPTANCE

The acceptance of the model was primarily due to three factors:

- the inability of the existing planning system to produce reliable figures either for the annual plans or for one-off analyses;
- the ability of the model to improve the performance in both these areas;
- the trivial running costs of the model of B.D.R.

The first has already been mentioned in several of the sections and is taken up again in Appendices 1 and 2. The other two are the subject of the present section and are covered more fully in Appendices 5 and 6. The section ends with a brief account of the course of the project from initiation to acceptance.

6.1. Results and Uses

Exhibit 5 illustrates the computer output for top management. This is a summary of the plans for a number of variables. It is explained in Appendix 5. The detailed plans went to line managers responsible for production planning, manpower, inventories and so on. The reports for line managers are not illustrated. Instead, examples of the output data from which they are derived has been included in Appendix 5.

The existing planning system was unable to match either the quality (optimum) or the accuracy of the report. Insofar as it could produce comparable information, gestation lasted from three to six months.

In contrast, the time required to collect the information, build the data deck and produce the results from the model was one week. The computer time involved was about half-an-hour.

To demonstrate its usefulness, the following situations were analysed, and the results presented to M-F management:

- monthly revisions to the production programme caused by new sales forecasts (previously these took over one month);
- the physical consequences and financial penalties of the policy for finished machines inventory (this had never been done before);
- the optimal plan for stopping production of an existing product in February with sufficient units in inventory to cover sales for the rest of the year;
- the impact on the assembly area of introducing a new product (was there sufficient capacity?, etc.).

Apart from these uses, other potential applications are such things as:

- Marketing - assess the relevant size, timing and nature of promotional schemes for individual products

  - determine the profitability of existing and the desirability of new product line policies.

Exhibit 5.

REPORT FOR M.D.

MANAGEMENT POLICY:MAKE BUCKET

PLANNING PERIOD :FROM NOV '71 TO OCT '72

DATE OF . SALES FORECAST:24/05/71

. COMPUTER RUN :06/06/71

DAYS MONTH	20 NOV	22 DEC	20 JAN	20 FEB	24 MAR	19 APR	20 MAY	20 JUN	15 JUL	15 AUG	24 SEP	20 OCT	239 TOTAL
FINANCIAL SUMMARY													F'000
REVENUE	388	385	499	590	572	617	451	469	517	431	399	442	5760
COST	-199	-267	-288	-225	-361	-314	-299	-317	-253	-241	-280	-318	-3362
CONTRIBUTION	189	118	211	365	211	303	152	152	264	190	119	124	2398
F.M.I.	102	144	142	22	50		33	72	17		36	89	59
													F
OVTM PREMIUM	-3748	-4932	-4854	-4824	-5608	-4212	-4450	-4955	-3909	-3895	-4785	-4931	-55112
SUBCON PREMIUM				-754		-4287	-2111		-825	-39	-138	-637	-8790
F.M.I. HLDG	-1578	-2775	-2194	-341	-969		-510	-1376	-258		-685	-1378	-12064
LOST SALES REV						29131	30654	53774	61729	50659		16876	242833
ACTIVITY SUMMARY													HRS'000
STANDARD HOURS	76	92	91	92	114	94	96	96	74	73	107	97	1102
MADE IN	76	92	91	92	114	89	94	96	73	73	107	97	1094
SUBCONTRACTED						5	2		1				8
MANPOWER (DIRECT)	174	188	204	215	220	220	220	220	220	220	220	220	212
OVERTIME - HOURS	5914	7642	7516	7551	8768	6541	6911	7763	6031	6014	7343	7713	85704
- PERCENT	21.24	23.04	23.01	21.96	20.76	19.56	19.63	22.05	22.84	22.78	17.47	21.91	21.36
SALES SUMMARY - %													%
FWDT	9.82	19.79	26.72	25.82	23.31	40.13	29.56	28.43	40.52	38.89	36.28	40.50	29.98
DRILL	9.31	15.10	13.75	11.63	6.82	1.29	.32	7.52	9.15	7.12	4.53	.	7.22
LOADER	9.08	8.41	9.61	8.19	7.88	8.97	8.09	9.61	7.85	7.04	6.98	7.88	8.30
DIGGER	71.92	56.75	49.97	48.50	54.80	46.19	55.82	51.90	42.49	45.46	38.69	43.25	50.48
BUCKET	.	.	.	6.02	7.35	3.50	6.42	2.51	.	1.73	13.70	8.38	4.14

- Personnel - identify future manpower needs
  - isolate the impact the cost of recruiting and the delay in training has on production plans and profits.
- Facilities - give advance warning of the need to change the investment in either general purpose or special purpose equipment
  - estimate the cost savings to be expected from such investments.
- Production Control - analyse the consequences of changes in productivity
  - the same for increases in the mobility of labour.
- Finance - make it possible for financial constraints to be built into the drawing up of plans rather than being tacked on to the end
  - quantify the results of changes in the method of paying direct labour.
- Purchasing - evaluate the merits of single or multiple sources of supply
  - determine the consequences of suppliers failing to meet delivery dates.
- Managing Director - supply quick and reliable data to assist in deciding many policy issues
  - identify the main areas for profit improvement
  - isolate the major threats to the achievement of targets.

These give some idea of the areas in which the model has a contribution to make. Appendix 6 gives results for a few specific cases. But even so, the model's potential is far from exhausted.

6.2. Cost/Benefit

The cost/benefit analysis for the project is given at the start of Appendix 5. One or two of the more important details are:

- total annual running costs for analyst and computer of £2,500;
- implementation costs of about the same amount;
- the implementation and first year running costs are covered twice by projected first year savings.

The development costs were funded by an S.S.R.C. grant.

The intangible benefits to top and line managers were thought by M-F to more than justify the project. The opinion was also expressed by a director that the construction of the model by itself, had taught management a great deal about the way decisions were interrelated and the manner of approaching problems of resource allocation.

6.3. Implementation

As mentioned at the beginning of this section, the decision to use the tactical planning model was made for a variety of reasons, and one way of explaining the contribution of the different factors is to trace the course of the project from the initial project proposal through the development phase to the final decision.

Before doing this, some background information should be given about M-F's top management in the U.K.

The rate of turnover in top management reflected the rapid worldwide growth of the company over the last decade: assets employed have more than doubled. The project was originally sponsored and periodically reviewed by a number of directors of the U.K. company. The membership of the committee was constantly changing. This soon created a difficult situation in which all the directors were new and had inherited the project and their membership of the committee. Therefore none felt as responsible for its progress or as involved as would have been the case if some of the original members had remained.

6.3.1. Initial Project Proposal

After one false start, obtaining permission for the project was not difficult: the development costs were very low, the problems were becoming an embarrassment, the intangible benefits were obvious, and the payback promised to be less than one year.

Some of the problems frequently recurring at that time were:

. the inability to decide whether there was enough general capacity to enable a new product to be made at B.D.R.;

. uncertainty as to whether the estimates of either direct variable costs or decision costs in a new product analysis accurately reflected the manufacturing interactions between new and existing products;

. the inability to determine whether the unexpected sales order should be accepted, rejected or postponed, i.e. there was no way of discovering whether their production was technically feasible or financially worthwhile;

. in general there was no method for evaluating the consequences (either physical or financial) of different policies affecting either the demand for or supply of resources.

It was decided to form a committee to monitor the progress of the project and to make decisions about its direction and scope. The members of the committee comprised the directors of the functions most intimately involved and my supervisor, Professor B. T. Houlden.

6.3.2. Evolution of the Project

Having identified the main problem area and obtained the approval of the Review Committee for the conceptual solution, it was necessary to construct the planning model and demonstrate its use. There were a number of design criteria I thought desirable for the collection of data, the construction of the model, the performance of the model and the creation of confidence.

- Data - The model should be small enough to make it feasible to manipulate the data deck by hand.

  - Line management should identify themselves with the model, it was to be their planning model, therefore the model was to be built according to their wishes. I should not second-guess the information they supplied although critical questioning was necessary to uncover the assumptions that lay behind the data and to obtain more detail and perhaps accuracy where the data appeared faulty. Changes to the model were to be the result of line managers reacting to the output and modifying their input.

- Construction - The model should be formulated to use an existing L.P. code, even though this might have redundant facilities. The reason was that this approach would be quicker and cheaper than coding a special purpose program.

  - The variable names should be immediately recognisable mnemonics, in order that the standard computer output would make sense; thus postponing the necessity for writing a report-generation program, which could come later.

  - The emphasis should be on achieving a significant improvement on current practice rather than building an elegant or intellectually satisfying model.

- Confidence - The model was to stay within the threshold of change to which the organisation could adapt. This implied firstly that the requirement for new data be kept to the absolute minimum, even at the expense of building the model around inadequate or erroneous data, and secondly that the model produce the familiar reports, as well as the new ones.

  - Confidence in the model should be established at the bottom of the hierarchy, with the cost department and the supervisor of production control, etc. No move to a higher level was to be made before the immediate subordinate was enthusiastic supporter of the project.
- Performance - The model should primarily (a) satisfy the practical problems of planning, and (b) be acceptable to M-F.

Either despite or, in part, because of these factors, the model was developed and met with increasing acceptance. One of the major stumbling blocks was the natural unwillingness of people to accept solutions to problems which they had previously learned to regard as one of the trials of life.

6.3. Final Acceptance

One of the surprising factors to emerge was that practically no one at M-F, from the directors down to the supervisors was concerned with how L.P. worked. In fact it was this misunderstanding on my part which slowed down the initial progress. I attempted to explain to the Review Committee how I intended to achieve the promised results. The mention of a computer model was right, while an explanation of L.P. was not. In fact, not only was the attempted explanation not required, it was actually disfunctional in that it reduced the director's confidence.

The final presentation to top management was made to an entirely new Review Committee. None of the members had had any previous contact with the project. It was obviously out of the question to attempt a resumé of the project, its current status, and the results. Instead, I prepared a simple, non-technical presentation on the theme: problems, solutions, results. The latter consisted of computer output in the form of both handouts and slides.

The meeting revolved round a discussion of the computer output. This, together with some preparatory enquiries made by the Assistant M.D., was sufficiently convincing to secure the decision to implement the project.

The general feeling at this meeting was that the model was a top management decision-making tool, and as such should be the responsibility of the personal assistant of the director of manufacturing responsible for all the plants in the U.K.

6.4. Extending the Model

Besides accepting the model of B.D.R. the Review Committee raised the question of applying a similar approach to the other plants in the U.K.

A meeting was held with the director of the Banner Lane factory and he expressed considerable enthusiasm, while cautioning that his problems differed from those at B.D.R., and would probably involve another formulation.

It was recognised that the third factory, Kilmarnock, had much in common with B.D.R.

The possibility of integrating the three models to cover the trans-shipment and sourcing problems was also discussed. It was decided that before pressing ahead with the new areas, experience should be gained with the existing model.

7. OTHER APPLICATIONS

The close of the body of the dissertation is given to considering whether there is a class of problems corresponding to the framework of the problem at M-F.

7.1. Manufacturing Industry

It should not be thought that I am suggesting that the approach taken at M-F can be slapped like a poultice on to the production and corporate planning problems of the rest of manufacturing industry.

In the first place, M-F had reliable and well-documented data for both production and costs.

Secondly, the data was relevant. Thus, time study had established 'allowed times' for each operation; production engineers had produced routing sheets; there were procedures for authorising and implementing changes to the specification of a product or the process of manufacture; and so on.

Thirdly, the planning philosophy was firmly embedded in the company at all levels. People were prepared to give time and ideas to the attempt to improve the planning systems.

Fourthly, management was open-minded about new techniques and was prepared to accept or reject them according to their merits. This is not to say that there was no resistance to change, but that the resistance was open to evidence and persuasion.

At the beginning of the dissertation I suggested that M-F was typical of manufacturing industry, and, by implication, that it was probable that other members of the industry suffered from many of the same problems, whether in the narrow context of production control or in the wider context of overall resource allocation.

The car industry is a good example of where the problems might be similar to those at M-F; a machine shop with three lathes making shackle pins an example of where the problems would be different.

The relevance to other manufacturing companies of the approach taken at M-F depends on:

- the scale and complexity of the manufacturing process;
- the nature of the manufacturing technology; reasonably stable relationships between factor inputs and product outputs, for each product; as well as substitutability of factor inputs between different products (men and machines can work on different products);
- the nature of the finished product, in that scheduling products is an important step in the planning of capacity;
- it being possible not only to change the allocation and utilization of factor inputs, but also to change the supply of the factors over time;

- the influence on costs and profits of variables which are linearly related should justify the expense of building a computer optimisation model;
- the short-run marginal cost curve should either be an increasing function or convex, and in both cases capable of approximation by linear segments.

Most of the above characteristics are to be found in some combination in manufacturing industry. In principle, the M-F approach should be capable of application to other companies in the sector, with some modifications. In practice, the candidates are more likely to be reduced by lack of appropriate data than lack of relevant problems.

Burbidge's book describes the data one would expect to find in, or which could be generated for, manufacturing industry. M-F data, together with adjustments which had to be made, are described in Appendix 7.

7.2. Other Industries

In looking outside manufacturing industry for sectors in which the approach could be applied, it is necessary to distinguish between the different strands of the approach. Some are of more general relevance than others. The main strands are:

- L.P.
- Activity values of interdependent variables should be planned simultaneously.
- Functional data is not necessarily appropriate for corporate tactical planning.

- Budgeting is a medium for expressing the results of tactical planning, it is not a good vehicle for carrying out tactical planning.
- The assumptions behind establishing direct costs in manufacturing are not valid for planning, i.e. changing the volume and mix of production should be evaluated in terms of the supply and utilization of a resource, manpower.

L.P. is probably the least general of the components of the approach. Its use requires firstly that L.P. is relevant, and secondly that the potential benefits justify the costs.

The assumptions of L.P. are proportionality, additivity, divisibility and deterministic. Each of these is discussed, and the usual source of violation indicated.

- Proportionality - both the objective function and each constraint must be linear. This implies that costs and revenues and factor inputs must be linearly related to the level of the appropriate activity. However, with a careful definition of variables and costs it is possible to achieve both linearity with respect to each variable individually, and a quadratic function when groups of variables are combined. For instance, the unit cost per product and the unit cost per man can both be linear, and the marginal cost of production quadratic - this is the case with the model for M-F. One important non-linearity is the 'set-up' type of cost.

- Additivity - not only should the objective function and each factor input be directly proportional to the level of each activity on its own, but also there must be no joint interactions. Joint-products and by-products are the most usual exceptions to this rule. For manufacturing, the assumption means that the cost and resource inputs of each product on its own is independent of the production levels of other products.
- Divisibility - the variables must be able to take on non-integer values. In other words, either they must be capable of infinite divisibility or it must be reasonable to approximate their planning in fractional terms. The M-F model, for instance, planned manpower and production in fractional terms. The numbers were large enough for rounding not to be inappropriate. One type of indivisibility is investment in new facilities. A new lathe adds, say, eight thousand standard hours of potential capacity per annum.
- Deterministic - all the coefficients must be assumed to be known constants, and it should be adequate to explore the effects of uncertainty either with parametric programming or by revising the model and reoptimizing. In the manufacturing model, the sales forecast was assumed to be a reasonable guide to actual sales, the standard hours per product for each department were assumed to reflect likely operating efficiencies, and so forth. If the

system is characterised more by randomness than stability, L.P. is not suitable. In some cases stochastic programming can be used to accommodate randomness.

It is difficult, without detailed knowledge of individual industries, to say of one that L.P. is relevant and of another that it is not. M-F, at first sight, fell into the class of problems in which production-smoothing formulations were relevant, on closer inspection there proved to be a number of non-linearities which, in the event, could be described in linear terms. There are no a priori reasons why M-F should not be typical of a class of manufacturing problems nor why the problems of manufacturing industry should be so distinct from those of other industries that similar approaches are necessarily ruled out.

This is a weak form of generalisation to other industries, but rash is the man who commits himself to building a good L.P. model for either an industry or even a company without detailed knowledge.

The other components of the approach do not need elaboration; for instance, the second point about activity values of interdependent variables is true irrespective of the sector. The question is more likely to be whether the objective is realisable (suppose the interdependence is non-linear, etc.) not whether the statement is relevant.

In summary: the least general of the components of the approach is L.P., here the restrictive assumptions of L.P. limit its relevance. The other components are of more general relevance outside the manufacturing sector.

7.3. Developments

There are two immediate directions which developments could take:

- Improve the correspondence between the model and the system it describes by such things as including the nightshift as a separate variable, including work-in-progress, allowing for set-up times.
- Widen the boundaries of the model to include the distribution system, other factories, etc., perhaps using a decomposition approach of, say, Beale to provide the linkages between sub-models.

Quite another type of development is to integrate it with M-F's computerised I.P.C. system and to build-in some predictors of factory-generated decision costs.

While the first two developments are largely a matter of replication, the third would involve much more research.

A final example would be to convert the model to produce P/L accounts and balance sheets as well as the existing schedules.

The weaknesses of the model are a corollary to the developments. In addition, then, to those already implied, should be specifically mentioned the eventual need for integer values for variables such as investment in new capacity, where linearity is not a good approximation.

APPENDIX 1

PROBLEMS

THE ORIGIN OF THE PROJECT

CONTENTS

PROBLEMS

1. INTRODUCTION

The purpose of this appendix is to discuss the specific problem that initiated my research, to show how this led to the discovery of a Pandora's Box of planning problems, to describe the selection of one or two key areas to be tackled first and to trace the process by which the symptoms can be generalised to become what I have called 'The Corporate Planning Problem', which is described in Appendix 2.

On the next page there is a schematic representation of the stages in the project, with comments outlining the motivation for each successive move. It was a question of problem analysis and cost/benefit. The objective was not to come up with the illusive total management information system, but rather to define an area in which significant improvements could be made at low cost and with the minimum initial disturbance to the existing systems and people. Hopefully, an innovation acts as a catalyst, but I thought it important not to exceed the threshold of change to which an organisation can adapt.

This last point is very important when it comes to implementation. The fewer demands a system makes both for new data and for the understanding of new reports the easier it will be to implement. The implication of a policy of minimum disturbance is that the sequence should be

Exhibit 1.1

DEVELOPMENT OF RESEARCH PROJECT

STAGE	FOCUS	OBJECTIVE	ADVANTAGES	DISADVANTAGES
Antecedent	Absorption Costing	allocate all costs to products	planning is deceptively easy	erroneous results from marginal analysis
Antecedent	Direct Costing	only identify costs which vary directly	fairly precise marginal costs	no help with decision costs
1	Prediction of Decision Costs	isolate factors which generate each cost	planning decision costs no longer arbitrary	requires data on levels of factory activity
2	Production Planning	production smoothing	reconciles conflicting requirements	data and techniques inappropriate
3	Corporate Planning Problem	rational allocation of company resources		

$$\begin{tikzcd} \text{analyse problem} \arrow[r] & \text{collect data} \arrow[r] \arrow[l, bend left] & \text{formulate solution} \arrow[l, bend left] \end{tikzcd}$$

instead of the more usual:

$$\begin{tikzcd} \text{analyse problem} \arrow[r] & \text{formulate solution} \arrow[r] & \text{collect data} \end{tikzcd}$$

In the latter the emphasis is on intellectual respectability, while the former is a more pragmatic approach. Perhaps this overstates the dichotomy. But it is my serious suggestion that a significant improvement + implementation should be the primary motivations.

Having briefly touched on the objectives which guided the development of the project, I turn to the development itself.

2. ANTECEDENTS

The project started with management's wish to find a reliable means of predicting decision costs. However, the story begins slightly prior to my direct involvement.

Becoming increasingly unhappy with both the effort of predicting the behaviour of costs and the intuitive unreasonableness of the figures once they had been computed, the company decided to change from absorption costing to direct costing. Direct costing was considered to have several advantages:

- inventory profits and losses caused by variations in production volume are eliminated
- management thinks in marginal costing terms
- it facilitates planning and control
- product costs are more accurately described.

As a consequence, management felt more confident in its ability to predict the outcome of changes in volume or mix. On the other hand, the primary disadvantage was the existence of a proportion of total costs (20%), called decision costs, which management knew would often be affected by decisions but for which there was no automatic means of prediction.

The effect of the change on the classification of costs is shown in Exhibit 1.2 overleaf.

COMPARATIVE COST BREAKDOWN

STANDARD FULL ABSORPTION COST		STANDARD DIRECT VARIABLE COST	
Direct Material	60%	Direct Material	60%
Direct Labour	10%	Direct Labour	10%
Variable Overhead	10%	Direct Labour Operating Allowances	6%
Fixed Overhead	20%	Processing Supplies & Scrap	4%
	100%		80%
		Decision Costs	20%

Exhibit 1.2

Since there was no formal method of generating decision costs, their estimation tended to be arbitrary and consequently a source of conflict. In the final analysis it was a matter of one man's opinion against anothers.

My research project was born out of the attempt to find an answer to this dilemma: the old system was all-embracing and inaccurate; the new was accurate as far as it went but did not go far enough.

3. STAGE 1 - PREDICTING DECISION COSTS

The initial investigation pursued three courses:

- an examination of the way decision costs were estimated in practice
- statistical analysis of past data using multiple linear regression
- discussions with the heads of budget centres to discover if there were any behind-the-scenes rules-of-thumb.

3.1. Current Practice

The outcome was rather what one might have expected: an improvement was possible but only after the planning of direct variable costs had been reorganised. Going into a little more detail: the company uses a planning system called Integrated Planning & Control (I.P.C.), which bases the new budget on the current year's actual results. To be more precise, the plan evolves in the following manner:

  Latest estimate of current Year End (9 months actual)
+ Carry-over
- One-time
+ Environmental
= Planning Base
+ New Management Action
= New Plan

i.e. this constitutes a series of systematic adjustments to the latest estimate of the current year's actual results.

If, for any, reason, the consolidated profit for the company is inadequate, theoretically there would be a loop round the last two items, in practice it is not quite as simple as that.

Later on we will see how a corporate tactical planning model interfaces with the I.P.C. system, in Appendix 6.

The weaknesses of this approach when applied to decision costs, and incidentally management's reservations about it, are illustrated by the way the planning game is played. Top management will arbitrarily instruct, for instance, the General Factory Manager (G.F.M.) to reduce his decision costs by x%. This never happens to direct variable costs. As an amusing example of the rules of the game I tell the story of a G.F.M. who was caught in this manner one year, and sweated blood to find the x%. The next year, having learned his lesson, he 'plugged' his decision costs by at least x%, carefully distributed over the different expense categories. The expected instruction never came; he had the greatest difficulty in legitimately overspending by x%!

The disadvantages of the I.P.C. system are:

- it fails to identify the factors (variables) which generate an expense
- it does not necessarily question the efficiency of the operations in the base year
- it fails to relate the change in the expenses to the changes in the activity levels which generate them.

If the impression is that this adds up to a complicated game of bluff, in which the objective is to secure as large an allocation of company resources as possible, this could well be correct. Moreover, it does emphasise the difficulty of verifying the estimates thrown up by the budget centres and the arbitrariness of attempts at profit improvement. The main justification for a blanket instruction such as 'reduce all inventories by y%' is the hope that it will be ignored by line managers when to carry it out would produce a nonsense. The heart of the matter is that management has little idea of how the company is articulated and, in general, no means of evaluating the consequences of different policy decisions. To parody this top management philosophy it could be described as 'kick everyone until they squeal'. Hardly a rational process of resource allocation!

3.2. Statistical Analysis

The attempt at statistical analysis was no more promising. Mostly, all indices of company activity, and therefore expenses, moved in sympathy, and the unexplained variance was too large for this method of prediction to be of value. For instance, I found that practically everything was related to the general level of production in the current month. Leads and lags of a month or so did not materially alter the correlation coefficient. And even supposing useful relationships had been established, they would probably have been statistical or permitted rather than causal; with the threat that the model would perform badly in anything but a stable or or slowly changing environment. Gershefski has constructed a model in which the coefficients in the regression equations are regularly updated by an analysis of the immediate past, and he says it works reasonably well. But input to his corporate model also includes a large number of estimates by management which could not be generated from regression equations. My own experience is that industrial data on levels of activity and categories of expense is so bad as to be virtually useless for statistical purposes. There is never enough information to make all the corrections necessary to render the analysis valid and the figures comparable.

3.3. Rules-of-Thumb

The last line of approach, discussions with those responsible for budget centres, proved at first sight to be more promising. The foremen and section leaders had a very good idea of the factors which generated the expenses under their control. It could be a cause and effect relationship (we need .....), a statistical relationship (we find .....), or the result of a policy decision (we always .....). Although it was theoretically possible to gather the data and build a model, it would have been exceedingly complex (similar in many respect to bill of material processing - B.O.M.P.), in danger of being inflexible, of doubtful cost/ benefit and, most important of all, it would require data on future production programmes, manpower and overtime which was not available.

The significance of this last point is established by the fact that production programmes and manpower plans are the basis for deriving the direct variable cost of production.

3.4. Summary

It became apparent that whereas management was unhappy about its ability to predict and control decision costs, in fact there were major shortcomings with the plans for direct costs. Apart from the latter being a much more important cost category, it was not possible to improve the planning of decision costs without first improving the planning of direct costs. Before I leave the planning of decision costs, I ought to say that a model based on the opinions of supervisors, etc. seems to me preferable to one using a large number of regression equations.

4. STAGE 2 - PRODUCTION PLANNING

Production Control is the department in the factory responsible for production scheduling and manpower planning, and consequently for determining the most influential constituents of financial plans: profits, cash flow, premiums, inventories and so forth.

It is my contention that production planning, encompassing as it does the horse-trading with marketing, is financial planning. Or to express it another way, financial plans are largely the natural consequence of production plans. There is of course a domain that is the sole preserve of the financial experts, for instance, such things as capital structure, the integrity of the financial control systems and so on. But the roots of most financial plans can be traced back to the production area. To give just one example: suppose the financial director wishes to explore the consequences of reducing the bank overdraft by £x during the year; far from being a constraint imposed on the financial plans at the last stage of the planning process (the traditional approach), it should be a constraint on the marketing/production plans at the beginning.

The realisation that production planning is profit planning materially alters the manner in which the planning process is conceived and the method in which it is executed. This theme will be taken up again in Appendix 2 on corporate planning problems. In the present section I describe the traditional approach to production planning, discuss the problems it leaves unresolved and show how they led me on to the wider issues of corporate planning.

4.1. The Objective of Production Planning

The function of production control is to turn a requirement for products (sales forecast + finished machines inventory policy) into the production programme which, while satisfying all the other manufacturing constraints, minimises the fluctuations in labour loading. In other words, the objective of production planning, in the medium term, is production smoothing.

The first point to note is that the objective is an example of the dichotomy between being production oriented and marketing oriented; the supremacy of either view leads to suboptimisation. The motive for production smoothing is to further the narrow interests of the factory. The rationalisation for this behaviour is the implicit and true assumption that big changes in factory activity cause expensive premiums and the unquantifiable disadvantage of labour unrest. However, it takes no account of the penalties incurred by other parts of the organisation as a consequence of this policy; the implication being that a certain amount of fluctuation in activity may be justified by the benefits accruing elsewhere.

For a moment I want to look at the situation through the eyes of the factory manager and see whether the policy of production smoothing, in terms of labour loading, is even in his best interests.

I suggest that labour loading is the wrong objective for the following reasons:

- it assumes that minimising fluctuations in activity necessarily minimises factory costs
- it is difficult to decide when the smoothing process should stop

- the process does not take into account the fact that the labour force shrinks through natural wastage
- the smoothing is done in physical units, whereas the criterion should be financial and the contraints physical
- it does not include all the sources of capacity.

I do not think that any of these points require further explanation. The most important mistake in the production planning system was to confuse a constraint and an objective. The objective should have been to explicitly minimise costs, subject to the contraints on labour loading and so forth. Instead the objective was to reduce fluctuations in activity to an acceptable level. In summary, even with a parochial view, the objective was wrong and the problem inadequately described.

4.2. The Process of Production Planning

The first step in the production smoothing process was to treat the requirement for products as a production programme, and work out the manpower needed in each department in each month. The result was always unacceptable to the factory. Seasonal sales were reflected in peaks and troughs in the activity of the productive departments. The next step was colloquially referred to as 'massaging'. Initially, the attempt was made to smooth activity by scheduling products to be made earlier than they were required by marketing; in the interval they went into finished machines inventory against the factory budget. Invariably the moving forward of production was only partially successful and the final resort was to move production backwards, so the products were available after marketing had nominally sold them. As can be imagined, this generated much conflict and many acrimonious exchanges.

Whether the system is called 'hunt and peck' or 'trial and error' does not alter the inadequacy of using experience and a desk calculator to schedule the production of 9 products through 9 departments over 12 months. With this method it took over 1 month to produce and agree a production schedule. As new sales forecasts came out monthly, the factory was always working on obsolete information and could be in the ridiculous position of implementing a production programme (hiring men, ordering materials, etc.) which was the exact opposite of the policy implied by information already available within the company.

Appendix 7 on data collection and data conversion gives more details of the production scheduling process, and specifically explains the linkage between products and direct manpower.

4.3. The Results of Production Planning

Production control issued two reports which summarised the results of their planning activities. The first was a production programme, and the second a schedule of departmental standard hours and manpower. Extracts from the old versions of both are shown in Exhibit 1.3 on the next page.

Starting with the production programme: the 34.7 Drill is a very good example of the inherent weaknesses of the 'massaging' process. Seeding occurs, at most, twice a year, which is reflected in the pattern of sales. It may well be that in the case of drills a postponed sale is

PRODUCTION PROGRAMME AND MANPOWER SCHEDULE

1971 PRODUCTION PROGRAMME — 2nd October, 1970

MACHINE	Days	20	22	20	20	25	18	20	20	15	15	24	20
	Month	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
	Prog.	100	110	100	100	100	72	60	60	45	45	48	40
	Cum.	100	210	310	410	510	582	642	702	747	792	840	880
34 Drill	Daily	5	5	5	5	4	4	3	3	3	3	2	2
Opening Inventory	Sales	77	149	194	157	84	14	26	106	109	8	-	-
105	Cum.	77	226	420	577	661	675	701	807	916	924	924	924
	Inv.	128	89	(5)	(62)	(46)	12	46	Nil	(64)	(27)	21	61

DEPARTMENTAL STANDARD HOURS & MANPOWER — 27th October, 1971

DEPARTMENT	Days	20	22	20	20	25	18	20	20	15	15	24	20
WELDING	Month	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
Std. Hours		90	99	92	92	116	83	93	92	69	67	95	78
Std. Hour Perf. %		220%	-	-	-	-	-	-	-	-	-	-	220%
Manpower		256	256	260	261	263	263	264	260	260	255	225	220
Subcon. Std. Hrs.		5	5	5	5	6	5	5	5	4	4	5	4
Manpower		23	23	23	23	27	23	23	23	18	18	23	18

Note: The standard hours are in thousands

Exhibit 1.3

a lost sale, for fairly obvious reasons. However, despite the necessity for meeting sales the finished machines inventory goes negative for three months consecutively at the beginning of the year and for two months at the end. This surprising result is the consequence of marketing refusing to rephase the sales forecast, a euphemism for losing sales, and the factory being unable to meet all the demands placed upon it. In this situation marketing 'goes on allocation', which means that marketing refuses to negotiate and requests the factory to say what products will be available and when. The factory then 'does its best', but the criterion for choosing between products is the physical one of standard hours required and available, rather than a financial one.

The last stage in the planning process was the most surprising of all. Once a year plans are drawn up for the next fiscal year by months and the following two years by year. If marketing and production control fail to agree on the production plans and marketing 'goes on allocation', instead of treating the production plan as the marketing plan, which is the case when marketing can sell all that can be produced, each submits its own plan. Given a large product line and financial summaries, the inconsistencies are impossible to discover. They only become apparent when working in physical units. Consistency is easier to achieve when plans are drawn up than when they are consolidated. Mistakes discovered at the latter stage involve laborious replanning.

The second document concerns departmental standard hours and manpower for each productive department. A summary sheet, which is not illustrated, provides the information that the effective (usable) manpower in the welding department at the start of the planning period (November 1st) would be 210. In the light of this, how is the schedule to be interpreted? The manpower line indicates that in November there will be 256 men's worth of work to be done, i.e. this is effective manpower and does not allow for absenteeism, etc. Each man can work up to 25% overtime per week. So our 210 men will be adequate, provided 27 men's worth of work is subcontracted in March and between 18 and 23 men's work for the rest of the year. The schedule says nothing about the effect of natural wastage on the department, nor what the overtime policy should be, nor whether it is genuinely better to subcontract 23 men's work rather than employ another 18 men and have them work overtime. Although it does indicate the general workload on each department, the fact that costs are not included in the evaluation process means that management still has to work out the consequences of different policies on hiring and firing, overtime and subcontracting. Moreover, there is the suspicion that the production programme and manpower schedule would have been different had these other factors, and especially the costs, been included ex ante rather than ex poste.

Once again, I must emphasise the complete absence of any financial data.

5. SUMMARY

Here I wish to draw together some of the criticisms mentioned earlier and set the stage for the next appendix on corporate planning. To summarise the deficiencies of production planning:

- the objective was wrong
- the system was inadequately described in that some important variables and constraints were omitted
- the method of processing the data was inadequate for the task, insofar as the processing time was greater than the interval between decisions
- no goal-searching technique was used, so that trial and error had to continue until satisfactory results were obtained
- trade-offs had not been systematically explored and sometimes the results were obviously nonsense
- many decisions which could and should have been built into the production smoothing process had to be taken subsequently.

At this point the problem looks like the conventional one of production smoothing. The motive for pursuing the initial problem of predicting decision costs this far was that the plans for direct variable costs and the physical quantities they represented were inadequate. The physical units of production and direct manpower were planned by production control, so it was a logical step to look at the objectives and methods of production smoothing. Having sorted out production and manpower scheduling and hence the planning of direct variable costs, why did the project move on to corporate planning instead of back to decision costs, the original area of interest?

If one were to have stopped at this stage, the solution to the problem of production smoothing might well have been to include and minimise costs, to use linear programming and to broaden the description of the problem area to include the possibilities of, and therefore to explore the trade-offs between, overtime working and subcontracting. The direct variable cost of each product was known, as was the capacity of each productive department and the physical overtime that could be worked. Finally, there were proven L.P. packages for most makes of computer, so the solution, as distinct from the formulation, should have presented no difficulties.

However, having realised that production control not only controls production programmes and manpower schedules but also determines total direct variable costs (plus some associated decision costs), and being aware of the number of management decisions which either directly involve or have an impact on production programmes and manpower plans, it is reasonable to explore to what extent production control was conscious of its wider sphere of influence, and top management of the deficiencies of the planning process. The deficiencies, if substantiated, were not of trivial importance but represented major flaws in the theory and practice of planning.

APPENDIX 2

PROBLEMS

THE CORPORATE PLANNING PROBLEM

CONTENTS

CORPORATE PLANNING

1. INTRODUCTION

In the present appendix I describe what I have called 'The Corporate Planning Problem'. It is, I believe, endemic to many companies once they have passed the stage where entrepreneurial ability and enthusiasm are capable of retaining effective control over all the major activities. The problem has something to do with the difficulties of planning and controlling the allocation of resources once responsibility is delegated and functions become specialised.

I have seen no evidence (which proves nothing) to suppose that the problem is confined solely to M-F or indeed to manufacturing industry. Apart from one or two exceptional companies such as I.B.M.,the problem usually becomes more acute with increasing size. The approach I adopted for M-F is explained in Appendix 3, it is less general than the problem; but with minor reservations, should be applicable to manufacturing industry.

To reiterate the motives for widening the scope of the research project to include corporate planning:

- Despite the factory accounting for at least 70% of all costs and a similar percentage of new and existing investment; production smoothing, the primary method of resource allocation, insofar that it preempted a significant proportion of company resources, was concerned with neither costs nor profits; the objective of production control was a satisfactory labour loading.

. Top management was continually making decisions about the product line, sales, production and manpower levels, sourcing of parts and products, and so on, without knowledge of the consequences on the key-variables and without a systematic examination of other possibilities. This is sometimes colloquially referred to as 'seat of the pants' decision making.

The remainder of section 1 elaborates these two points in the context of their impact on the process of allocating resources.

1.1. Satisficing

The diagram overleaf, Exhibit 2.1, helps to illustrate the point that as costs only enter the planning process after the production programme has been agreed, and profits even later still, the negotiations between marketing and the factory were restricted in their aim to establishing a feasible production schedule rather than an optimal financial plan.

In other words, the objective was to find a production programme which was acceptable to the factory and to marketing. The latter were satisfied if their requests for units for sale and inventory were met. The former were satisfied if there were no violent fluctuations in activity.

The discussions between marketing and the factory centred around production volume and timing. While the internal procedures of the factory were concerned, in the first instance, with standard hours, it was assumed that if the capacity was available or could be found, the factory would meet marketing's request for products.

PRODUCTION SCHEDULING AND PROFIT PLANNING

OBJECTIVE	UNITS
Market Share and Sales Revenue	Products
Smooth Labour Loading	Standard Hours
Direct & Indirect Production Costs	£
Earnings/Share, Profitability, etc.	£

PROCESS

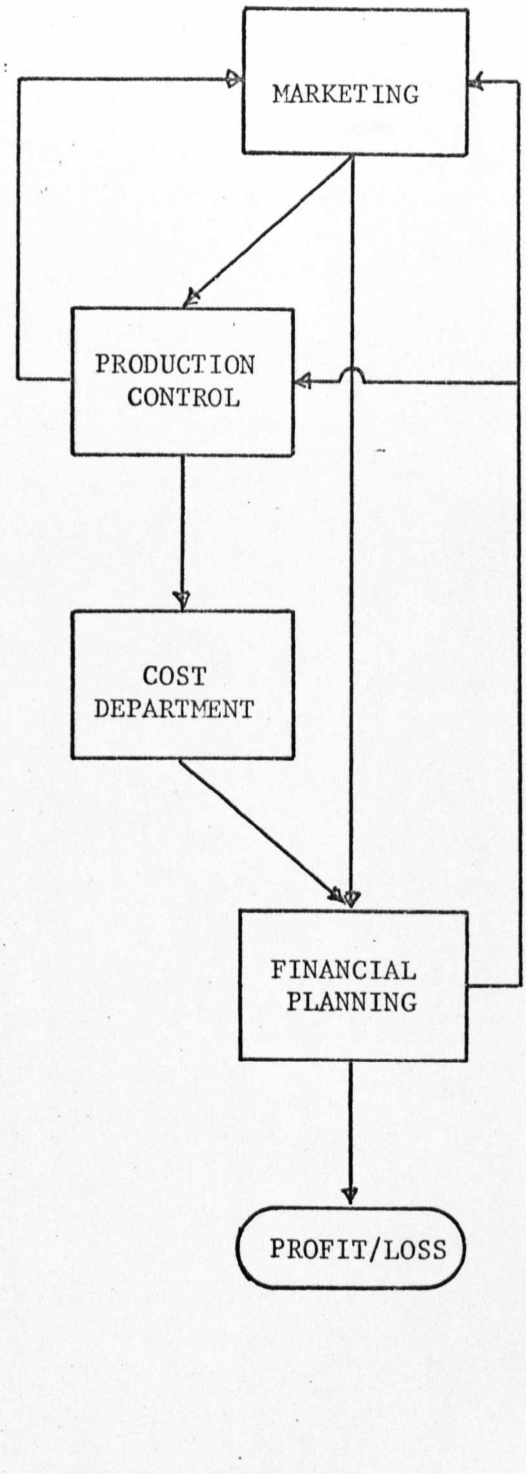


Exhibit 2.1

As can be seen from the diagram, the cost of the production plan was only known after the plan had been settled. And the profits from the combined production and marketing plans were only discovered after consolidation by corporate financial planning. At such a late stage there was little that the corporate planners could do to influence profits. All the important linkages between sales, production and factory activity had been swallowed up by the summaries submitted to them as functional plans. As a last resort, it was possible to recycle the planning process, perhaps once, in which case the plans were almost certain not to be ready in time for the start of the fiscal year.

The corporate financial planning department did not take part in the negotiations to agree a production programme other than initially supplying the planning guidelines and subsequently consolidating the functional plans.

To conclude that one answer is to bring costs and revenues directly into the process of production planning and to computerise the system is to misunderstand the nature of the problem. The different components of the method I used at M-F are described in Appendix 3.

The effect of including costs and revenues and using the computer is to speed up the calculations and use the financial consequences of a particular sales/production schedule as feedback to the negotiations between marketing and production control. There is no denying the extra information to be an improvement. But it does not go to the centre of the problem. In the first place it requires someone to specify the decision-rules by which all the trade-offs are to be made. Secondly, it is impractical to systematically explore by complete enumeration the feasible combinations when there are 9 products, 9 departments and a 12 month time horizon. Thirdly, it begs the question about which figures should be used for costs and revenues. As I show in section 2 of the present appendix, and in more detail in Appendix 7 on data collection and conversion, direct variable costs and company net return (sales price less discounts) are not appropriate. Lastly, there are a number of questions to which the corporate planners would like answers and about which the system envisaged above would be silent. These questions are considered in section 1.3 of the present appendix.

Another prescription might be that it would be a help if the corporate planners could become more involved sooner, so that they were in a position to influence the outcome of the production smoothing process and thereby establish some control over resource allocation. Such a development would be desirable provided the nature and scope of their intervention could be defined to everyone's satisfaction. But although it would introduce the profit motive into the discussions, it is not immediately clear how this would necessarily improve the outcome, unless some means could be found of incorporating the criterion of profit into the process of manipulating the data. As I mentioned earlier, the problem is so large and complex that recycling, by itself, is of little help.

1.2. Seat of the Pants Decisions

If the first motive for broadening the project to include corporate planning is summarised as the desire to introduce the criterion of profit into the system for production smoothing, the second takes the part of top-management faced with having to make strategic and tactical decisions with very little reliable and relevant data. Exhibit 2.2 shows the importance of tactical resource allocation in the planning cycle.

It can be argued that tactical planning plays a decisive role in the profit planning of manufacturing industry. By the time operations planning occurs, many commitments, whether to customers or suppliers, have already been entered into, and the objective is to minimise costs. Strategic planning often starts with an analysis of the strengths and weaknesses of current operations: much of the quantitative material in this analysis comes from tactical planning. For instance, I suggest that one of the explanations of the gap between the promise of strategic profits and the reality of current performance is the widespread inability of industry to assess the tactical implications of strategic plans. An example of using the model I developed to help with the analysis of a proposed new product is given in Appendix 6.

On the other hand, operational problems can generate a need for swift tactical planning. A good example would be an unexpected strike which disrupted production schedules and made it necessary to derive a new production programme and to decide which products should be given precedence. The task is not easy when the marginal cost of a product is

THE PLANNING CYCLE

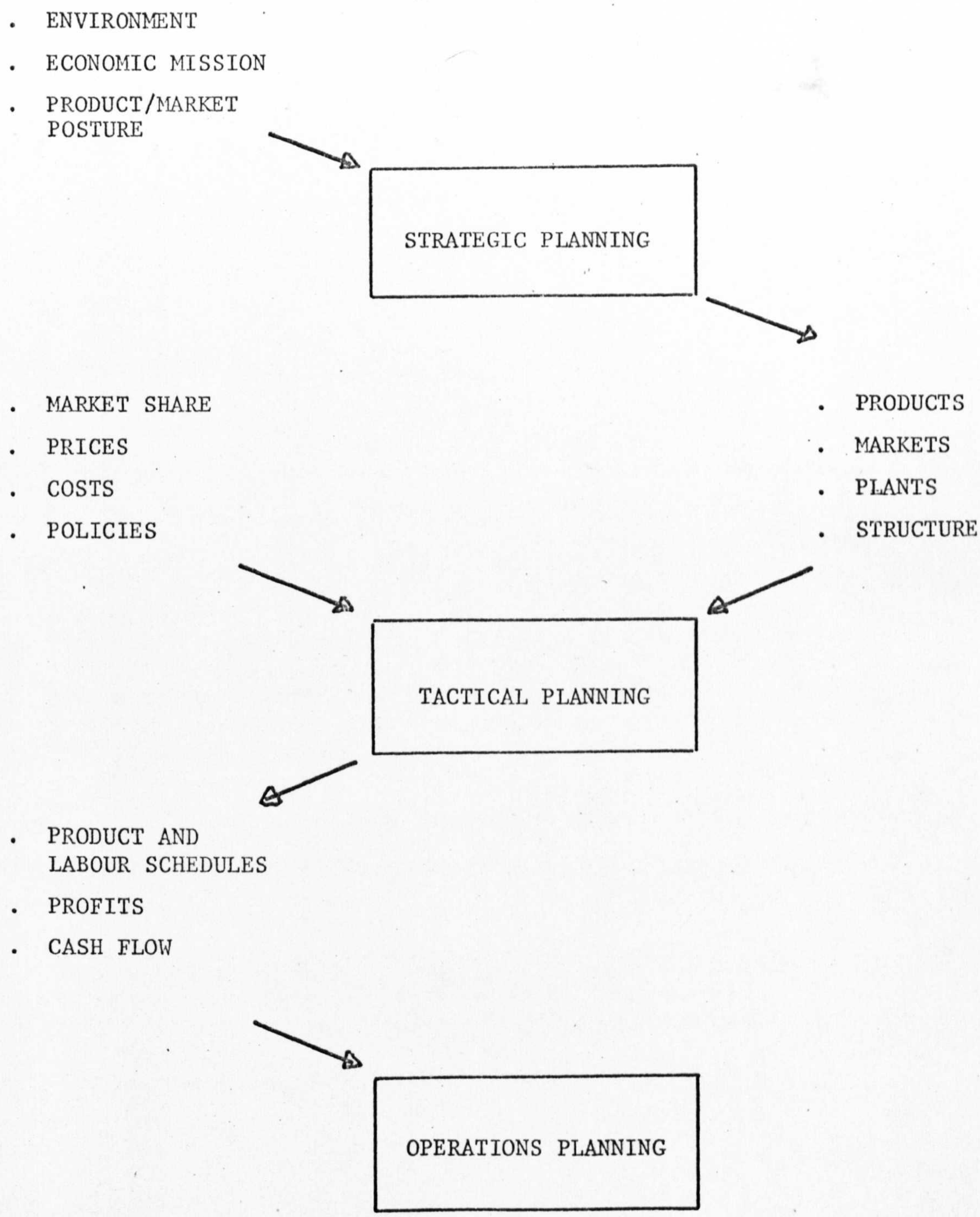


Exhibit 2.2

not its direct variable cost (the correspondence is seldom true) and when it it takes longer than one month to calculate a new production schedule.

Therefore tactical planning, besides being important in its own right, contributes to strategic and operational planning.

Without the means of quickly producing reliable tactical plans covering the main decision variables,management has to resort to such things as hunch, rumour, rules-of-thumb and pressure groups to guide them in reaching decisions.

It is partly because tactical planning is so badly done that the executives of manufacturing companies typically spend their time 'fighting fires'. Of course, industrial relations problems are a contributing factor, but some of the problems are caused directly by the inadequacy of the planning systems, and others by the inability to respond adequately to the unexpected once it has occured. One suspects that 'fire-fighting' could be self-perpetuating.

1.3. Unanswered Questions

A planning system should be capable of more than simply grinding out one set of consistent figures, although in many cases that in itself would be an achievement. Even the ability to repeat the performance several times, while perhaps giving a feel for the robustness of the plans over a limited range, will not provide much of the information that rational planning requires. There will still be too many unknowns surrounding the variables the company does control for there to be much confidence about decisions based on such plans, quite apart from being uncertain of the eventual state of nature.

Some of the questions corporate planners would like to ask are such things as:

- Does the marginal revenue of a certain policy exceed marginal cost?
- Have all the main possibilities been explored?
- How stable is the solution?
- Which factors constitute the greatest vulnerability?
- Which areas are most promising for profit improvement?

It can be seen that there is more to the answering of these questions than the mere processing speed of a budget compiler or the combination of regression equations,management data inputs and processing speed of Gershefski's simulation model.

However, despite fairly ready agreement on what the aims of corporate planning should be, the practice at M-F, and,as far as I can discover, most car manufacturers in the Midlands, concentrates on the three areas of: setting overall objectives, providing guidelines (and ensuring uniformity) and consolidating plans. Conspicuous by its absence is a means of analysis and review which wrests control of planning resource allocation away from the plants and places it in the hands of the chief executive.

1.4. Some Consequences

A glance at the previous diagram on production scheduling and profit planning shows profits to be the result of decisions instead of the criterion for choosing between possible courses of action. The consequence is that the final profit is the result of a mix of inter-related factors. The contribution of any particular component or group of components is unknown, lost in the aggregate.

Suppose that at the end of the day the planned profit falls short of the president's goal for earnings per share. A complete revision of the plans is impossible - in many corporations the cycle takes about 9 months. Another possibility is the adoption of one of the popular panaceas: cut all costs by x%, increase sales by y%, cut headcount by z%. There are many stories of cases where such an approach was not just shortsighted, but actually counterproductive. My own variant is of the severe pruning of a printing department, only a token labour force was left. Perhaps the hope was that the work would dry up - a corollary to Parkinson's Law - 'work contracts to meet the capacity available'. Since this particular department did a great deal of work for the marketing department, and since there were to be no changes in the product line or product literature, the printing originally done in-house was subcontracted. The headcount was down, total expenses up. Of course, this cause and effect relationship was disguised on the control reports sent to head office. The managing director received credit for carrying out so promptly and effectively the instruction to reduce headcount; the increased costs were all but lost in being aggregated with a large expense category and were explained by the bland 'adverse movement in environmental factors'. Perhaps the conclusion is either that the managing director was an astute player of the planning game or else that he was unaware of the consequences of his decision.

As experience with the planning system and its results increased, behind the specific examples of general inadequacy, it was possible to detect a number of issues which might be causing most of the trouble. These issues I have collectively called 'The Corporate Planning Problem'.

It would be inappropriate if the overall impression created by this account of either the people or the systems at M-F was unfavourable. In fact the opposite is the case. The project was born out of the desire to improve a system which, by the prevailing standards, was functioning reasonably well. Had the basic planning systems not been sound, the planning philosophy not been widely diffused throughout the company and the raw data not been in existence, my project would never have started.

The reason that the true picture does not come across in the normal course of the narrative is that it was the deficiencies which motivated the search for improvement.

2. THE CORPORATE PLANNING PROBLEM

The Corporate Planning Problem has a number of components which I first list and subsequently explain. The components are: conflict, consistency, data, optimisation, processing, profit improvement, sensitivity and vulnerability. Exhibit 2.3 shows the structure of this section.

2.1. Conflict

For whatever reason, the aspirations of an individual are not always compatible with those of other individuals in the organisation, nor do they necessarily correspond with the objectives of the corporation. Conflicts frequently appear in their most acute form during the planning process, when individual targets are set and the resources of the company allocated to the divisions, departments and budget centres.

The planning process should be conceived with awareness of possible conflicts in mind. Such an approach implies that, firstly, the quantifiable consequences of different courses of action should be known and agreed upon by all concerned so that the area of uncertainty, in which the final decision has to be made, is reduced to weighing the risks and the qualitative elements. In other words, the quantitative factors are removed from the debate. Secondly, it must be possible to generate the quantitative data with sufficient speed to permit the evaluation of various options and the revision of basic policy. Thirdly, the control and auditing procedures should be capable of relating outcomes to forecasts. This can only be done if both forecasts and results are held in the same

THE CORPORATE PLANNING PROBLEM

COMPONENTS	PARAGRAPH
Conflict	2.1.
Consistency	2.2.
Data	2.3.
- detail	2.3.1.
- assumptions	2.3.2.
- omissions	2.3.3.
- interactions	2.3.4.
Optimisation	2.4.
Processing	2.5.
Profit Improvement	2.6.
Sensitivity	2.7.
Vulnerability	2.8.

Exhibit 2.3

disaggregated form and classified by project, budget centre and time period as well as the usual expense categories. Lastly, the planning unit should have some independent means of verifying the reasonableness of forecasts and requests. This is one of the tasks Bower assigns to his 'integrators'. Again, there are numerous stories of a new project being loaded with unnecessary new investment in order to kill it, or having vital expenditure omitted to save it, or having irrelevant investment added because the profitability can stand it. An example of a realistic approach to the need to verify estimates and resolve conflicts is given in Appendix 6 on using a corporate planning model.

2.2. Consistency

The extracts from the sales and production plans shown earlier are good examples of the type of inconsistency which can occur and the manner in which they arise. The problem is due to the unfortunate coincidence of a number of factors: planning being done sequentially, i.e. estimates go from marketing to the factory, on to the cost department and so forth; the time delay this involves; the pressure to revise the data to include the latest estimates. Together, these factors make it very difficult to ensure that all the parts of the organisation are working with the same version of the data or even on the same assumptions. The task of ensuring consistency once the separate plans have come to head office is virtually impossible, even if the plans are broken down into units in which the inconsistencies can be discovered, i.e. physical units as opposed to financial summaries.

It is one thing to have plans which are too ambitious - the behavioural rationalisation would be to call them 'demanding and achievable' - it is quite another when the individual targets and action programmes are mutually exclusive.

2.3. Data

In a different category of significance from the other components which characterise the corporate planning problem is my suggestion that for a number of reasons tactical planning should not be the extension of operations planning. In other words, apart from the sequence in the diagram on production scheduling and profit planning being a source of error, the concept it represents is mistaken.

It conceives of planning in terms of information flowing through the various departments. Each department in turn processes the information, seeks clarification from and supplies feedback to departments further upstream and eventually produces its own plans. By the time the plans reach the stage of consolidation, several types of error have accumulated; detail, assumptions, omissions and interactions.

Some of the reasons for errors occuring and accumulating are:

- Systems for monitoring the current activities of a company tend to collect operational data. For want of a better alternative, the relationship between variable and activity is often interpreted as independent and dependent variable respectively and used as a predictor. So there are reports on the number of direct workers employed each week and the wages bill, the weight and the value of material delivered broken out by main categories, etc. Frequently such operational data and relationships are not suitable for tactical planning. For example, it would be incorrect to plan the payroll for direct workers by using past data on the relationship between manpower and total wages. The independent variable for wages is not just manpower. There are several independent variables, all of which must be estimated, such as, the relative sizes of the departments, productivity, capital intensity.

- Where data is generated specifically for planning, while fulfilling the primary role satisfactorily, it may be inappropriate for other uses. Some of the arguments for a standard costing system are that it is a help in pricing, valuing inventory and planning the costs of manufacture. However, it would be wrong to use the standard costs for (a) new product analyses, (b) looking at sales mix and production mix, (c) deciding on the allocation of existing and procurement of new resources.
- The data available within each function may be adequate for the activities of each in isolation, but insufficient for them jointly. At B.D.R., production control issued a production programme - products, manpower - which was sent to the 'factory' department. The latter had to supply products according to the schedule and was responsible for production facilities and manpower. The manpower figures on the production programme

were not instructions as much as an indication that the programme had been smoothed. The factory department then developed and pursued its own manpower policy. If production fell behind the schedule, the factory department apologised. One of the reasons for the discrepancy between required and achieved production was that the factory's ability to hire and fire had not been expressed as constraints on the process of production scheduling by production control. In fact neither department knew what this constraint was. The need for it only became apparent when viewing their joint activities.

. Apart from such unintentional causes of error, there are those introduced purposely. The production control department was continually second-guessing the marketing forecasts. The worst incidence of second-guessing was in the magnitude and the lead-times each link in the procurement chain built into his request for products to guard against non-delivery by the preceding link.

. Finally, it is worth mentioning that each function filters the information, sent to others; partly because not to do so would swamp the system, partly because of the territorial imperative, partly in the interests of the recipients to select for them the relevant information.

For a number of reasons, then, errors appear to be inherent in the planning system unless their presence is realised and action taken to identify the variables and their characteristics required for tactical planning.

The rest of the section is an attempt to indicate the type of errors that can occur. It trys to answer the question 'what sort of errors should

I be looking for?'. Whereas the earlier part of the section was concerned with why errors occur.

2.3.1. Detail

There is no difficulty if the requirement of corporate planning is for less detail than is supplied by the functions and it can be met by aggregating existing categories of data. However, what happens if a different breakdown is required, say by project rather than budget centre, or by time period?

Unless the specific needs of corporate planners have been built into the planning guidelines for the functions, any analysis which is not functionally oriented will be difficult.

Although such a step would be an improvement, it is not the whole story. Let me draw an illustration from my research. I discovered that the data used by production control was suitable for labour loading but inappropriate for the larger issue of resource allocation. To put it very simply, neither the plans they submitted nor the data used to generate the plans took into account the problem of machine loading. The information I required could not be obtained from the published documents of production control, but was available from detailed records within the department. It took someone who was familiar with both production control and corporate planning to unearth the deficiency.

2.3.2. Assumptions

Another type of error is that the implicit assumptions on which the data is based, while being valid operationally, need not be valid for tactical planning. An example is the direct variable cost of production. This is defined as the increase/decrease in costs from making one more/less unit of product. The main categories are: material, labour, labour allowances and processing supplies and scrap. The direct labour cost is made up of the clock hours required for a unit of product plus an average bonus payment. It is implicitly assumed that there is a constant relationship between products, clock hours and men. This is not true. Men are frequently employed even though there is insufficient work to keep them all busy in the immediate future. So, in fact, management has two distinct choices, the first is whether to employ a man, the second is whether to give him work. The effect of making this correction is shown overleaf. A method of allocating resources which assumes a constant relationship between products and men does not permit the evaluation of the major options, especially towards direct labour, which are open to management.

Importantly, not only are the assumptions obscure to those outside the cost section who request data from it, very often the assumptions are so enshrined in the operations of the cost section that no one inside thinks of questioning the assumptions. Moreover, members of the cost section are unlikely to spend much time thinking deeply about the relevance of cost data to situations being analysed by another department; the presumption is that the questioner has done his homework, and anyway there is a continual stream of such requests.

DATA ERROR

The direct variable cost of a product is taken as the marginal cost for all planning horizons.

The standard direct variable cost of a product is not its marginal cost for tactical planning. Two corrections are necessary. The first is to subtract the amount representing the day-wage of labour. The second is to subtract the cost of freight.

The effect of these two adjustments on the Drill is shown below.

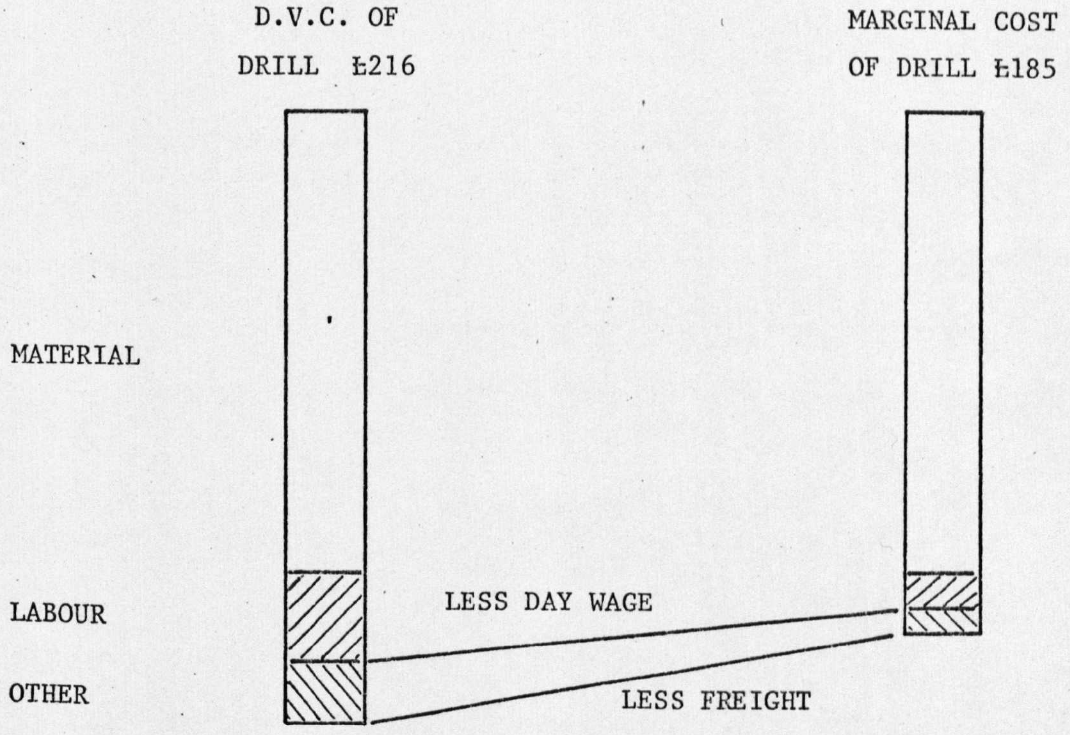


Exhibit 2.4

I have used the cost section to illustrate that whatever the source of data it needs to be checked not only for accuracy and general relevance but also for the assumptions on which it is based.

2.3.3. Omissions

This is a variant of the mistake of sub-optimisation, with the emphasis now on the wrong variables instead of on the wrong objective function. Although, naturally, the former implies the latter. Viewing corporate plans as the product of consolidating functional plans often results in an incomplete description of the demands for and sources of capacity, and also of the possible exchanges between sources of capacity within a month and from one month to the next. Specific examples are: failure to include finished machines inventory as a source of stored capacity (previously it was simply the balancing item), treating sales as an exogenous instead of endogenous variable, failure to include the costs of hiring and firing, and so forth.

If the problem is inadequately described it is difficult to weigh up the possibilities in a realistic manner.

2.3.4. Interactions

Strictly speaking, the lack of the proper interactions is as much an omission as the lack of the proper variables; both cause the problem to be incorrectly described. However, I wish to distinguish between failure to identify the right variables and failure to quantify the relationships between them. The former is dealt with above, the latter now. In fact all relationships were omitted except for the link between products and labour content via standard hours and standard hour performance. In other words, there were no limits on such things as the rates of change of capacity or the maximum rate of production due to the shortage of supplies.

2.4. Optimisation

With all the usual caveats about size, relevance, run times and flexibility, I take the arguments in favour of an optimisation model to be decisive. The reasons are set out below.

Corporate planners need a model which is capable of two extreme modes of operation (and, of course, any shade in-between):

- On the one hand,it must be able to evaluate the consequences of different policies expressed in terms of point values for all variables; this is what I call the non-discretionary mode of operatibn. The model is doing nothing which could not be done, albeit more slowly, on a desk calculator.
- On the other hand, it must be able to explore all the feasible possibilities and in a finite number of steps, a long way short of complete enumeration, identify the best solution; this is the discretionary mode.

(I should emphasise that these were the immediate requirements at M-F. Once supplied, it is possible to go on to such developmentsas stochastic models, models of the company and its environment, and so on.)

In other words, I view management as having set opinions about certain facets of running the company and being indifferent about others. Examples of the first might be: no overtime is to be planned for Sunday afternoon in order that there is room to accommodate operational problems; reductions in manpower are to be limited to natural wastage; the manpower in the primary department must be somewhere between 23 and 30. Where management is indifferent, typically a large area, the task of the model is to choose the most profitable combination of demands for and supply of productive resources. This embodies the idea that where all other things are equal (the area of indifference), the company would rather make more profits than less. An optimisation technique, when applied to financial planning, is nothing more nor less than a means of discrimination on the basis of profits, a method of choosing the more efficient from the less.

2.5 Processing

The justification for a model of any description, and particularly where a single mistake can be disastrous, is that it is better to experiment with a model than with the real situation. Planning models are no exception. A single planning cycle, for M-F and many other large corporations, frequently lasts from 9 months to 1 year, making it impossible either to try out a number of policies or to carry through a complete revision should the results prove unsatisfactory or to update the plans quickly should some major unplanned event occur (the expropriation of mines or oil supplies).

The vulnerability caused by a slow manual planning system is illustrated by the case of a large multinational company. At the final submission of the plans to corporate headquarters, the chief executive refused approval because the consolidated plans did not meet his target for earnings per share in the current year. It was not until 6 months of the planning horizon year had elapsed that the new plans were submitted and approved.

2.6. Profit Improvement

Under a system of Integrated Planning and Control (I.P.C.), a series of adjustments are made to the present year's actual results to arrive at the 'Planning Base'; this is the 'do nothing' situation - the outcome in the planning year if management takes no new action. Then comes 'new management action', designed to lift profits on to a new plateau. Typically, the new action will involve pricing, promotional expenditure, cost reductions, and so forth. One of the perpetual uncertainties in planning is whether some important area for profit improvement has been overlooked, i.e. what are the key areas for profit improvement?

I doubt whether many management teams would claim to know all the important factors limiting profits, or for that matter the particular contribution of those which they had identified. In these circumstances, it would be a great help to know the particular contribution of every variable. The type of information I have in mind is that if marketing were to reduce their minimum inventory of tractors by x units in month y, profits would be higher by £z. This is precise information about a particular variable and it is unlikely that management would have thought of asking the question which elicited such a specific reply. One of the problems of corporate planning is to be aware of all the key factors which limit profits.

2.7. Sensitivity

A great deal has been written about sensitivity analysis and I have nothing new to add. I mention it because it is important and to distinguish it from the problems of profit improvement and vulnerability analysis with which it is sometimes confused. Clearly it is important for management to know the robustness of the plans in the face of changes in the values of input variables. There are three facets to sensitivity analysis: the magnitude of the change in an input variable, the likelihood of the change and the consequences of the change. A deterministic approach handles the first and the last. Some variant of the Hertz method is required for all three. Implicit in the idea of sensitivity analysis is that the variable or combination of variables and the range of values are chosen by management.

2.8. Vulnerability

This is the last problem of corporate planning I wish to mention. In one sense vulnerability can be thought of as a comprehensive sensitivity analysis. Whereas sensitivity analysis answers the question 'what are the consequences of sales of tractors being down 5% over the whole year?', vulnerability analysis answers the question 'over what range of values of input variables is the final plan insensitive?'. Framed in such a manner it is apparent that this is a different type of question altogether. Instead of asking about the sensitivity of the solution to specified changes in particular variables, it asks about the range of values of all input values over which the solution is indifferent.

The motive for the question is to determine which estimates are critical to the achievement of the plan and therefore should be checked carefully to ensure their correctness and subsequently watched closely to monitor variances as they occur.

3. CONSEQUENCES

Enough has been said to indicate that the problems and their consequences were important. However, I would like to emphasise the contribution of tactical resource allocation not only within the framework of planning over different time horizons, namely operational, tactical and strategic, but also to most other planning activities of the company, whether it be capital structure (here the contribution would be through retained earnings and financial needs), the timing of a new product introduction (here, the feasibility and consequences for the factory), negotiations with the unions about mobility of labour (here, the premium which it would be worth paying to achieve mobility) and so forth.

Thus the consequences of not to be able to produce either valid or optimal tactical plans were far-reaching. Exactly how far-reaching can be appreciated by recollecting that 70% of the company's resources were effectively outside the control of the corporate planners.

4. SUMMARY

A schematic summary of the course of the whole project is given in the first table of the previous appendix. The following fills out that framework.

Full costing was a bad predictor of costs, so the company adopted direct costing. The latter was an excellent predictor of directly variable costs but no help with decision costs. The prediction of decision costs required data on the physical quantities represented by direct costs: products, direct labour, overtime, etc. This data was not generated in sufficient detail by the planning system. Production control was the department responsible for planning the physical units from which total direct costs were derived. The primary function of production control was to schedule production. In the course of scheduling production some 70% of the company's resources were allocated. Despite pre-empting 70% of the resources, production control was concerned with neither costs nor profits. It was difficult to understand how profits were planned or controlled. Corporate planners were ultimately responsible for planning the allocation of resources. Corporate planning was obviously done in a semi-vacuum because of the inability of the factory to evaluate the consequences of different courses of action. The difficulties with planning resource allocation were in part due to the way the planning process had been conceived and in part due to the way it was executed.

Some stages of the planning process should not have been done sequentially, because this prevented the exploration of the trade-offs between demands for and supplies of capacity. Furthermore, tactical planning should not have been the extension of operations planning because much operating data was unsuitable for tactical planning and the resource allocation process was incorrectly described.

The result was that there was no effective planning of or control over the resource allocation process.

APPENDIX 3

A POSSIBLE APPROACH

CONTENTS

A POSSIBLE APPROACH

1. INTRODUCTION

The objective of the appendix is to describe the changes I thought were necessary at M-F to improve the existing planning system and to realise the potential of the resource allocation model I had constructed.

In fact the sequence was the reverse of that just suggested. Having built a model which helped with a number of planning situations and crossed functional boundaries, such questions arose as:

- Who should be responsible for the model?
- How should the model be used?
- In what situations is the model relevant?
- Who should have access to the model?

Organisational difficulties were caused by the model's ability, for instance, to produce better production schedules than the production control department. Better, that is, by the criteria of production control as well as the corporate planners. I do not discuss the organisational problems.

The Assistant Managing Director decided that one of his staff should be responsible for the B.D.R. model. Implementation at B.D.R. was to be the first stage. It was envisaged that the possibility of extending the approach to other areas would be examined. That was to be the second stage. Use of the B.D.R. model would involve, embryonically, the planning scheme outlined in section 2 of the present appendix. However, formal change to the organisational structure and planning systems as outlined in this appendix would only be necessary if the model were to be extended.

It follows that this appendix is largely normative in that it suggests one way in which M-F could make use of planning models, covering all the plants, as part of the formal, day-to-day, planning and decision-making process. By implication, other companies in manufacturing industry, the data base and organisational structure permitting, could adopt a similar model and similar procedures.

Section 3 develops the outline of section 2, and explains the contributions individual components make to alleviating the problems mentioned in Appendices 1 and 2. Section 4 says something about the corporate planning department and model building.

2. THE GENERAL APPROACH

2.1. A New Concept

On the assumption that a rational method of allocating the resources of a company is a legitimate objective, I suggest the following scenario:

Step 1. Targets and general guidelines are sent to the functions by the corporate planning department.

Step 2. In response, the functions send data (not plans) to the corporate planners.

Step 3. The operational data is converted for tactical planning uses.

Step 4. The corporate planners, in collaboration with representatives from each function, run the corporate optimal resource allocation model. Strategies are tried out and refined, policy decisions are taken.

Step 5. The results of these decisions are embodied in detailed policy documents, setting out the pattern of resource allocation, which are sent to the functions.

Step 6. The functions draw up their detailed plans within the constraints laid down by the corporate planning department.

Step 7. The detailed plans are sent to head office where they are checked, consolidated, reviewed and submitted to the president.

Step 8. The president approves the plans.

It may not be immediately clear in what way this is a new concept. Perhaps most of the steps look reasonably familiar, if not in practice then at least from the literature.

I suggest that the solution is novel in specifically recognising two important factors:

- operational data may be inappropriate for tactical planning
- the process of consolidating and pruning functional plans cannot achieve the optimal allocation of resources in a situation where a change to the plans of one function alters both the demands for and supplies of resources from another.

The means by which these two are overcome are by (a) asking, in the first instance, for data which is then converted into a form suitable for tactical planning, (b) building the data into a model which includes all the important linkages both within functions and between them, and (c) resolving all these interdependent and conflicting demands simultaneously: thus eliminating the endless chasing of tails.

Looking at each step a little more closely may help to distinguish the new concept from the old:

- Step 1 is indeed the familiar one of setting overall targets, specifying the assumptions on such things as inflation and movements in exchange rates, outlining the products and markets for the coming year, and so forth. Additionally this step includes a list of unresolved issues, e.g. new product policy, on which decisions have still to be made and for which data must be prepared and submitted.
- Step 2 is the submission of operational data in accordance with the instructions of Step 1. An example of the form this could take is given in Appendix 7.

- Step 3 is the important process of data conversion. This is better done at the centre under the supervision of those responsible for processing the data than out at the functions. This leaves the corporate planners free to modify the data in parallel with the changing nature of the decisions to be made.
- Step 4 is the heart of the resource allocation process. Approximately 70% of the company's resources is allocated - all the direct variable costs and the premiums associated with them, as well as the major investments. These decisions set the framework for a number of other policy areas such as capital structure, short-term financing, the strengths and weaknesses of the current product line and production facilities etc.
- Step 5 can be viewed as a more detailed version of Step 1. It is important that the final results of consolidating the plans are still compatible with the targets laid down in Step 1. To this end, I would expect Step 4 to make allowances for the decision costs and peripheral investment needs (amenities, etc.) not included in the corporate model, and Step 5 to constrain the functions so that they stay within the limits.
- Step 6 is the detailed planning by the functions of all costs and investments, within the contraints agreed with the corporate planning department.
- Step 7 is the submission of the functional plans to the corporate planning department. They are checked for compliance with the instructions on direct variable costs and conformity with the restrictions on decision costs and investments. Provided there are no violations, the consolidated plans will be consistent with the targets established at the beginning of the planning process.

- Step 8 is the nominal one of approval. If the original targets of Step 1 are unattainable this will come to light at Step 4. The whole planning process is designed to minimise the possibility of last minute surprises and maximise the chances of a rational allocation of resources. The only reason for the president to reject the plans would be a major change in world or national affairs between Steps 3 and 4. Otherwise the profit pattern of resource allocation, etc. would all be in accord with his wishes.

The advantage of this system is that at a single stroke it achieves several objectives previously thought, in some measure, to be mutually exclusive:

- resources are optimally allocated
- corporate planners are not swamped by either a mass of detail or a large computer model
- head office retains both the responsibility for and effective control over resource allocation
- the functions play a constructive role in drawing up their own plans
- the final plans are achievable and consistent.

2.2. The Method of Execution

It is evident by now that I advocate the use of both the computer and an optimising technique. These replace respectively the desk calculator and trial and error. The technique most appropriate to the situation at Massey-Ferguson was linear programming (L.P.). The reasons for this choice are given in the next sèction of the present appendix.

My suggestions of L.P. and the computer (the former implies the latter) are not conditional upon the company having its own computing facilities; although this does have distinct advantages. The size and nature of the mathematical model I am proposing can easily be run on a computer bureau. In fact, all the output in the appendix on using the model came from that source. The run time never exceeded 10 minutes and was more often below 5 minutes than above it. The model was of a mythical company, making 4 products, in 3 departments, over a 13 month time horizon, with an annual turnover of about £5.5m. So even with bureau facilities the cost/benefit should be firmly positive; quite apart from the fact that there are few other methods of obtaining comparable information.

2.3. The Benefits

Without prejudicing the formal statement on cost/benefit, which is to do with the results of the planning process, I would like to consider the effects on the planning process itself.

Under the old, manual, trial and error method there was no knowing whether the plans were optimal, achievable or consistent.

The chief executive never knew on the one hand whether one more kick would force the last ounce of potential profit out of the company or, on the other hand, whether he had applied too much pressure, causing promises to exceed reasonable expectations - the expedient of buying time is very understandable behaviour on the part of a harassed executive. Firstly, his luck may change, and if the worst comes to the worst, he has longer to look for another appointment.

The proper use of an optimization model will indicate the profit potential. If, for any reason, management wishes to make non-optimal decisions, the model, in the semi-non-discretionary mode, will calculate the consequences. If, despite every endeavour, profits are still below the president's goal, the model will help evaluate extraordinary, and more risky, courses of action in the direct cost area: for example, such things as increasing labour efficiency, cheapening the product (euphemistically called 'value analysis'; Rootes/Chrysler cars are a good example).

There are numerous advantages from just computerising the planning process: one obvious example is the situation which involves revising the plans at short notice. At M-F it was frequently the case that as the year unfolded, sales did not run at the level anticipated when the plans were approved, variances built up between forecast sales and actual sales, and if marketing insisted that this was a temporary set-back and refused to revise their forecasts, the surplus production went into finished machines inventory. Eventually even marketing took their medicine, admitted a mistake had been made and that the original forecast was too high and revised their forecasts downwards. It was then necessary to reschedule production in the light of the new, lower forecasts and high inventories. If revising the plans takes two months, an already bad situation is needlessly exacerbated. A computer could produce the new plans overnight, and an optimization model would give the added assurance of choosing the most profitable path out of the mess.

2.4. Common Reservations

I have presented the benefits to the planning system as if they needed very little explanation, which I believe is true, and as if one could expect management, after a brief introduction, to regard these suggestions as the panacea for their planning ills, which is not true.

Whatever the final outcome, doubts can take one or more of the following forms:

- Usually the first one to be voiced is 'what happens if a major unplanned event occurs which upsets all the plans?'. The questioner seldom realises that not only is this an argument against planning (if it is against anything at all) rather than one against using computers, in fact it is the very reverse of what he intended; it is a situation which favours the computer system over the manual one.
- Another common objection is 'what about the unions?, have you included them in the model?'. The answer is that the model contains all the factors which can be quantified which affect the decision variables - many more than are included in the manual system. The purely qualitative factors are in neither system.
- There is often a question about detail, which takes the form 'part number M91 040993 K1 is causing a lot of trouble at the moment; the machine shop is breaking 1 in 3; it could be a faulty batch, on the other hand, this particular job is usually done by Bert, who has been with us since he was an apprentice 20 years ago, and he's been off sick since the beginning of the month. It could be that none of the others have the skill. Could your model cope with that situation for me?' If one takes the question at its face value, the reply is that this is a problem about scheduling parts, not about scheduling products, but insofar as the former affects the latter, the

model can easily be adapted to include it. However, if one judges the real motive to be insecurity, as I would be inclined to do, the reply is that the model has a number of shortcomings and , astutely, this question has pinpointed one of them.

- There is the notion that a manual system is inherently more flexible than a computer system. In one sense this is true. A manual system is capable of infinite variation. A computer model with anything approaching the same capability would be very expensive to develop and run, and at any one time would have many redundant features. However, over the range of variation encountered by most companies there is no reason why a computer model should not be as versatile as a manual system.
- Finally, there is a style of management implacably opposed to computerised planning and perhaps with reservations about the value of planning at all. Typically, such people say that they run the business 'by the seat of their pants' and that 90% of their time is spent 'fire-fighting'. There are others, myself included, who judge both these to be symptoms of bad management, the inadequate rushing from one crisis to another, each the breeding ground of the next.

3. THE SPECIFIC SOLUTIONS

3.1. Introduction

Exhibit 3.1 on the next page shows the problems, the deficiencies of the old manual system and the strengths of the new. It can be seen that the new approach is divided into three sections: concept, computer and L.P. (Together, the last two comprise the method of execution referred to earlier.)

The purpose of the diagram is to indicate the contribution made by each of the strands of the new approach. For instance, we see that use of the computer without L.P. (referred to in the literature as a 'budget compiler') only helps with some of the problems.

The rest of this section takes each of the problems in turn, and explains how each strand of the new approach contributes to its solution.

Before finally leaving the old system, it is worth noting that even taking a generous view, it compares unfavourably. Its inability both to describe complex situations in sufficient detail and to process the data is fatal for its claim for consideration as the major constituent of a management information system during the last third of the twentieth century. Techniques, technology and concepts make its redundancy increasingly obvious.

THE CORPORATE PLANNING PROBLEMS AND SOLUTIONS

	OLD	NEW		
	Manual	Concept	Computer	L.P.
Conflict		x	x	x
Consistency	x	x	x	x
Data - detail	x	x		
assumptions	x	x		
omissions		x		
interactions			x	x
Optimization		x		x
Processing			x	
Profit Improvement				x
Sensitivity			x	x
Vulnerability				x

Exhibit 3.1

3.2. Conflict

Each of the three strands contributes to mitigating this problem. Their combined effect is to reduce the area of uncertainty in which the final decision has to be made. This is achieved by removing the debate about the deterministic, quantifiable data from the arena. Agreement on the latter still leaves risk and qualitative factors open to differences of opinion.

The specific contributions are:

- Concept - provides reliable and appropriate data; achieved by operational data being corrected for tactical uses, resource allocation being done at the centre where all the demands for and supplies of resources are known, and where trade-offs can be explored, and by detailed guidelines being sent to the functions, restricting their room for manoeuvre.
- Computer - ability to handle the complexities involved in a realistic description of the system and to process the different views of the dramatis personnae.
- L.P. - the best solution to each combination of inputs, having examined all the trade-offs. Moreover, it is able to accommodate management's specific wishes about the value of certain variables and to optimise over the area of indifference.

Previously, differences in personal objectives were compounded firstly by arguments about whether the results of an analysis correctly reflected the consequences of a particular course of action; secondly, by the absence of any means of deciding when the company's overall objectives were best achieved, and thirdly, by the inability to run an analysis under a series of different assumptions.

Understandably, a 'one-shot' analysis producing suspect results tended to increase conflicts rather than reduce them.

For instance, at M-F the new product procedure was a continual source of friction. For this reason, an example of the introduction of a hypothetical new product is given in Appendix 6.

Quite apart from the benefits from processing the data, building a model has the advantage of isolating the data which must be estimated before certain types of decision can be made. L.P. adds information on how the accuracy of the estimates affects the results. So, for example, the inevitable comment that the production engineers are never within 10% of the real direct variable cost of manufacture is put in perspective as being critical, irrelevant, or somewhere in-between.

Without a centralised resource allocation model the corporate planning department was at the mercy of the functions and whoever had the president's ear.

The role of the corporate model is to help the corporate planning department 'hold the ring', to supply to the combatants data which is acceptable to them all, to give management the facility of playing the 'what-if' game. In other words, up until now the planning system was unable to respond to the legitimate demands for information imposed by the ordinary decisions of running a business. This worsened any natural tendency for there to be conflicts of interest. A functional director, if his will did not prevail, would have to live with and be responsible for the ill-defined consequences of decisions with which he was not in agreement and which were based on a somewhat arbitrary analysis. The new system helps alleviate this problem.

3.3. Consistency

Lack of consistency is one contributor to the problem of conflict. For instance, awareness that the latest production programme, issued yesterday, is at variance with the revised sales forecast, available a fortnight ago, naturally increases the number of areas of disagreement.

- Concept - physical and financial data is processed at the centre, replacing the former practice of submitting plans which were consolidated at the centre.
- Computer - comprehensive description of the relationships between the decision variables; the time taken to process the data being less than the interval between decisions.
- L.P. - the planning of all demands for and supplies of resources in the direct cost area is done simultaneously. This is important when a change in the value of one variable causes a bounded ripple effect as opposed to an unbounded effect. In the first case there is the rebound effect on the first variable, in the second case there is not.

Evidence of lack of consistency was only too common, and did not increase the executive's confidence in the basic data, the means of processing or the decisions based on it.

A frequent example at M-F was the factory's habit of having work subcontracted, which could technically be done in-house, and at the same time refusing the men overtime because there was not sufficient work to warrant it.

Such anomalies cast doubts on the value of any statement by the factory about its ability to make products, or for that matter, not to make them.

3.4. Data

The new concept plays the major part in providing an acceptable solution to the corporate planning problem. It is primarily concerned with the validity of the data and the process of allocating resources.

- Concept - in summary, the new concept is that tactical planning must not be the extension of operations planning, that resource allocation should be done on the basis of data and not plans, and lastly that resource allocation must be done at a level in the organisation which encompasses all the interdependent demands for and supplies of resources. Perhaps the best way of explaining the last point is that it must be possible to weigh the different trade-offs.
- Computer - without the computer a planning system had to be a coarse model of the company. There was no means of recording, updating and processing the complex relationships linking the variables. It was hoped that a global view of a few important variables would adequately describe the company, and whatever one's reservations it was usually better than nothing. In a stable environment this is probably good enough, for then past levels of expense and activity are good predictors. However, situations characterised by change and complex relationships make coarse manual models inadequate.

. L.P. - provides a structure for describing the company and a technique for manipulating the data. Both are important. Without a formal structure there is no motive to direct the search for data, no method of classifying it, no guide to relating it and no idea how to interpret the results. Without a technique for manipulation, articulating the model in the intelligent pursuit of a stated objective may be either theoretically or practically impossible.

Although the new concept represents the main innovation, L.P. and the computer were the medium for transforming an interesting idea into a present reality. In fact the formulation of the L.P. has a number of novel features which made it possible to reflect the wide range of choices open to management (a flexible approach to policies) and the many potential sources of capacity.

The effect of the changes mentioned in this section is summarised in section 2 of the present appendix. The objective is to remove control over and responsibility for the process of allocating resources to head office. This implies that the corporate planners should specify the data to be submitted by the functions, check the assumptions which lie behind the data they request and establish the relationships of variables both with functions and between functions. In short, they should use their vantage point to make sure that appropriate data is submitted to head office to permit the rational allocation of resources.

3.5. Optimisation

There are two facets to this problem. Firstly, what to optimise, and secondly, how to optimise. The answer to the first question distinguishes my approach from other applications of L.P. and other methods of corporate planning. The answer to the second explains why I used L.P. There is a separate appendix describing the formulation, Appendix 4.

. Concept - provides a management and user-orientation to model building. This concentrated on such questions as: what decisions are made most frequently?, what information and reports are used at the moment?, how can the information and the reports be improved to facilitate decision making in the most cost-effective manner? The complex conceptual scheme has been given earlier in this appendix, section 2. The new approach did necessitate many corrections to both the physical units of measurement and the costs of variables, with the result that the model accurately reflected the consequences of changes in the value of variables and also permitted the full range of policies to be tried out.

. L.P. - provides a cost-effective approach to optimisation. In the section on corporate planning problems in the previous appendix, I identified the need for a mathematical technique which was capable of being both goal seeking and a straight calculator.

I called these two modes of operation respectively, the discretionary mode and the non-discretionary mode. In the latter case the specific value of every variable may be input to the model, whereupon the model calculates the value of the objective function. It is this ability to set the value or range of values of particular variables which makes the model so flexible and able to accommodate many of the policies which affect the decision variables. For a variety of reasons, the optimisation technique I chose was linear programming:

(a) several reliable computer codes already existed, which therefore reduced the development costs of my project

(b) new problems could be formed by combining or adding to old problems

(c) advanced starting solutions enabled reoptimisation of a modified problem to start from an existing optimum solution; another cost saving feature

(d) post-optimal analysis provided a great deal of valuable information

(e) report writing languages existed for turning the results into a form acceptable to management; again improving the immediate cost/benefit of the project

(f) satisfying the restrictive assumptions of L.P. did not present insurmountable difficulties.

The net effect was to produce a compact model of the factors influencing the demand for and supply of about 70% of all company resources involved in the area in question.

The model was inexpensive to build and run, easy to maintain and flexible. Some of the management reports it produced are shown in the appendix on using the model, Appendix 6.

The result was to provide management with a quality and variety of information, of considerable help to the decision-making process, which previously had been unobtainable. And, moreover, for the information to be available within a couple of days of formulating the policy.

There are arguments in favour of using a simulation model instead of an optimising one. There are circumstances when these arguments would be decisive. This is not one of them. The claims for a simulation model are:

(a) it can incorporate any type of relationship

(b) it is frequently cheaper to build

(c) it is much cheaper to run than the corresponding L.P. model

(d) it is more flexible

(e) it can get within 5% or 10% of the optimum solution

(f) it does not require such highly qualified staff as an L.P.

To deal with these very quickly:

(a) true, but irrelevant if non-linear relationships are not required

(b) false, unless the user intends to write his own L.P. codes, which seems pointless, in the first instance, when so many good codes exist for all the important makes of computer

(c) true, provided the number of sensitivity analyses is kept firmly under control

(d) false, most L.P. codes are good, it is possible to search out a bad one

(e) possibly true, but at the expense of considerable increased man/model/machine interactions

(f) true, but you get what you pay for, and the cost/benefit analysis should help with this one.

The immense advantage of an L.P. model becomes apparent, if it not intuitively obvious, when one tries to build a simulation model. There are a vast number of situations in which there are several possible courses of action and no clear method of discrimination other than profit. The solution would seem to be to incorporate the relative costs into rules of thumb for the programme to use as each situation arises. Hence, normal overtime is cheaper than Saturday overtime and should be used first. But this overlooks two important factors. First, it is not input costs but marginal costs that matter. Secondly, the number of tests the computer would have to perform to be sure that it was selecting the cheapest possibility would be enormous. For instance, the simple distinction between the two rates of overtime completely misses the point. Just a few of the other potential sources of capacity are: normal overtime the previous month, higher manpower, higher inventories; or another approach altogether: lower sales because marginal costs exceed marginal revenue.

The advantages to resource allocation of a system which automatically discriminates on the basis of profits clearly outweights, in such a situation, a system which lacks this ability.

3.6. Processing

There are many arguments against and in favour of using the computer for data processing. In general they are well known, and I do not think it necessary for me to rehearse them, except insofar as they are relevant to my project:

- Computer - provides the only means of solving an L.P. of more than trivial size. The most significant use of computers is to perform those tasks which are impossible without them. An optimum resource allocation model is one of those uses. The combination of the computer and L.P. not only produced better results than the manual system, it was actually cheaper as well.

Having solved the L.P., it saves time and lessens the possibility of errors (transcription and calculation) if the subsiduary reports are generated on the computer by programmes with direct access to the original data and the solution. At one stage I was doing these calculations by hand, and it was very time-consuming, boring and easy to make errors.

Another advantage of the computer is the flexibility it provides in generating the maintaining the data. The data is constantly being modified to reflect new policies, each month it is revised by the addition of the new month and the deletion of the old, new products are included to test out sourcing decisions and product line strategy and so on. The computer makes it possible for the model to reflect management's changing perception of the problem and the search for new courses of action.

3.7. Profit Improvement

There are two components to the search for greater efficiency and higher profits. On the one hand there is new management action. These could be plans to reduce absenteeism or to raise the standard hour performance or to lower the scrap rate. The model is able to evaluate the consequences of such actions. On the other hand there is the systematic analysis of the influence every variable has on profits once the best solution has been reached.

. L.P. - provides the shadow prices of all relevant variables. Without becoming technical, two pieces of information are supplied: the profit improvement (it can be negative) caused by increasing the number of the particular variable in the final solution by one unit, and the range over which this profit improvement (marginal profit) is valid. The significance of this information need not be stressed. A report automatically focuses management's attention on those variables which could make the biggest contribution to increased profits.

Therefore, not only will L.P. evaluate management's schemes for profit improvement, it will also suggest schemes. Given the complex system of interlocking relationships which characterise a manufacturing and selling organisation, it is unlikely that management will foresee the impact each constraint and each restriction on the value of a particular variable, will have on profits. This works both ways. Some factors thought to be important may turn out not to be, and others thought to be insignificant may have far-reaching consequences.

3.8. Sensitivity

Sensitivity analysis has already been defined as the exploration of the consequences of changes in the input value of key variables; for example, what happens if sales are 5% lower than forecast? Because it is the input value which is changed, this means that the variables and their new input values must be selected by management. The motive is to get some feel for the possible consequences of the uncertainty in the original figures and thereby to assist in the formulation of a policy towards the risks.

- Computer - it is the speed and flexibility provided by the computer which makes possible trial runs on a number of different values of input variables
- L.P. - mistakenly, L.P. is sometimes thought to be inferior to simulation models in its ability to perform sensitivity analyses. This is by no means an inherent weakness of L.P., although it may be true of certain L.P. codes. The one I used, MPS/360, could not be faulted on this point. It was a case of either using the model in the non-discretionary mode or of using parametric programming, a process by which multiples of a change vector are added to the values of specific variables.

3.9. Vulnerability

This is another unique feature of L.P. and one of the reasons for choosing L.P. in preference to other optimisation techniques. One of the arguments advanced to discredit the use of any optimisation technique is the uncertainty of the estimates in a planning model which spans a 13 month time horizon. The reasoning goes: how can you justify a search for the last 5% or 10% of profits when the uncertainty in the basic data is at least as big and may even be as much as twice these amounts?. In fact, far from being an argument against L.P., uncertainty is an argument for it.

- L.P. - provides a systematic analysis of the manner in which uncertainty in the input values of the variables affects the optimal solution.

The best plan for allocating resources will probably be very sensitive to the value of certain inputs, less sensitive to others and almost completely indifferent to others. The effect of vulnerability analysis is to identify those input values which should be estimated carefully and watched closely, and those which are not in need of such care and attention.

4. FROM THEORY TO PRACTICE

4.1. Introduction

While the cost/benefit gives a payback of less than a year, and the intangible benefits might well be considered sufficient to justify the project on their own, I do not want to gloss over the implications this approach to corporate planning has for the corporate planning group and for building a corporate planning model.

4.2. The Corporate Planning Group

The first point I want to discuss concerns the corporate planning group: its name, role, composition and responsibilities.

I have carefully not referred to the process of corporate financial planning, which is what most people have in mind when they talk about corporate planning. The reason corporate planning, either in name or substance, should not primarily be concerned with financial planning is that it is impossible to allocate resources in an optimal manner by playing around with financial plans. The unpalatable fact is that if the functional plans are inconsistent, sub-optimal and unachievable when they arrive at head office, no amount of wizardry by corporate financial planners will rectify the matter.

The problem is not new, and attempts to overcome it tend to concentrate on prevention; recognising that cure is difficult, if not impossible. Prevention often takes the form of some combination of planning guidelines plus corporate 'travelling circus'. The latter probably consists of a group from head office who discuss and review plans with the functions as they are being drawn up. This is a help. However, if all three problems are to be adequately resolved then I suggest the answer is an approach very similar to that which I have outlined.

In which case, the corporate planning group is doing very much more than produce financial plans, although the financial plans are the natural consequence of the group's activities. It is also doing more than is implied by the term logistics, which is commonly used to refer to planning the flow of materials and products. In fact its activities span all the usual functional areas. Perhaps it is best called 'The Corporate Planning Group'.

The group has a formidable task. It is not only responsible for building and running the resource allocation model, but also has to specify the input data. The planning cycle starts with the group issuing guidelines on the functional data to be submitted. They then convert the data for tactical planning: changing the degree of detail, aggregating it differently, modifying the assumptions and the data to reflect the objectives of resource allocation and so on. The model is continually being adapted as management formulates new policies to be tried out, new products come along; in fact all the demands for information on the tactical implications of strategic and operations planning must be accommodated besides tactical planning in its own right.

The decision about the skills to be found in the planning group determines the success or failure of the whole concept.

There are those who take the view that the group should consist of financial experts who can call upon the backroom boys (a collective noun for: computer specialists, O.R. workers, production engineers, etc.) as they are needed to perform specialist tasks, such as building the model.

My experience is that this view is mistaken. Firstly, because it is difficult to make intelligent use of a model at arms length, i.e. without being aware of how it has been constructed, its limitations, the logic, its potential, etc. Secondly, it is equally difficult to communicate to someone else (a professional model-builder) how the model is to be constructed without becoming intimately involved in its construction. It is not possible to say blandly 'build me a corporate resource allocation model'.

My suggestion is that the group should have within it all the skills necessary to build, run and maintain the model and to advise top management. This will include the ability to collect and convert the data from production control, to unearth the assumptions which lie behind the cost data, and so forth.

The model spans all the functional areas; the group should be multi-disciplinary.

I realise that a frequent panacea for people at the top of large organisations who feel they have lost control to the échelons below, whom they suspect of filtering out too much or the wrong information, is to create a new group directly responsible to the man at the top - what better precedent could there be than the cabinet office and Lord Rothchild's think-tank?

However, if the planning group is to have a model capable of determining the best allocation of resources under any given set of circumstances, and if strategic, tactical and operational policies are to be tried out on the model, then the group should have access to whatever body or whichever individual wishes to control and is responsible for the allocation of resources.

The group is responsible for turning policies into inputs to the model and presenting management with the quantifiable consequences of these policies in a form which is meaningful and can be understood. Examples of some of the ways complex information can be communicated are given in Appendix 6.

4.3. Model Building

In a book on simulation models, Goldie lists his complaints about models under the headings of lack of responsiveness and lack of confidence. In the former category are:

- models take 3 to 4 times as long to build as promised
- it takes a long time to incorporate a change
- the data is not readily available.

In the latter category he mentions:

- the model is never quite right
- the problem to be solved has to be translated into the model's terms
- the model cannot be explained in understandable terms

. the process being simulated changes faster than the model can be changed

. no-one can define the probable range of error in outputs.

He is probably expressing the reservations many executives have about computer planning models. And in this appendix I not only advocate use of an optimal resource allocation model, but also suggest that for some industries there is no comparable alternative - comparable, that is, in terms of cost/benefit - for a certain range of planning activities.

Goldie's reservations can be turned round to imply the properties of an acceptable model. They can be summarised by saying that the model should be small and flexible, should use existing data, be easy to validate and should indicate the consequences of the probable error in inputs.

Perhaps I could illustrate these points with reference to my resource allocation model.

Without wishing to play down either the work that went into developing the model, or the interesting formulation, my model, as far as models go, is small. It is compact enough for the card deck to be manipulated by hand should the necessity arise. The reason is that the deck represents data and not data + programme. This is a point which is often overlooked. A change to a simulation model which means reprogramming, to an L.P. model means more data. The latter is the easier to accomplish.

Goldie's comment about data raises several issues. My experience is that it is possible to achieve a worthwhile improvement over the manual system with a relatively small model. Three attributes of my model are that it uses existing data, it presents output in a form familiar to management and, consequently, it is within the threshold of change which the company can assimilate. The model is not perfect. The suggestion is that the model should be built around existing data - albeit converted - and make as few demands as possible for new data. It is better that expensive data collection be initiated by a user, who has reservations about the validity of the output, than by the model builder.

The last two implications from Goldie's article concern validation and ranges of output values. Validation is a useful process for the model builder: it provides the opportunity for reassurance that no important variable has been omitted, no untenable assumption made, no relationship incorrectly described, and so forth. There are two complementary approaches to validation. The first is to test the model out on the limit: put in large opening inventories, close down a factory for two months, group all the sales at the end of the year, etc. The second is to run the model in parallel with the existing system and reconcile discrepancies. While the manual system cannot hope to reproduce the results of the L.P. from the inputs, it can work backwards and check the results and the inputs for consistency.

I am not sure that I fully understand Goldie's point about the range of error in outputs. A corporate model consists of inputs, relationships and output. Uncertainty may be associated with either of the first two. With a deterministic model, if the range of possible variation is known, the consequences can be explored with sensitivity analysis. The probability of a certain variation and the attitude to risk must both be assessed by the decision-maker. The contribution L.P. makes to the question of risk is firstly information about the range of variation in the value of input data which can be tolerated before the optimal solution changes. And secondly the consequences changing input values has on output values.

Goldie's experience at Boeing was with a deterministic simulation model. If he judges randomness to be the most important characteristic of planning activities, then maybe he ought to consider developing a stochastic model. Depending on the source of randomness, stochastic programming could be relevant. Alternatively, he could try a stochastic simulation model.

However, his views are interesting in that they represent the attitudes a model-user has to model-builders and models. It is difficult to say how typical he is. Elsewhere in the article he claims to be a supporter of the idea to use models for planning and controlling complex operations.

5. SUMMARY

The solution strategy had three prongs: a conceptual approach, the use of the computer, and resource allocation through optimisation. Between them they go some way to resolving the corporate planning problem as I perceived it at M-F.

The heart of the system is the concept which proposes (a) the submission of data by the functions to head office, (b) data conversion, (c) optimisation of the demands for and supply of resources (simultaneous solution), (d) the submission of plans by the functions in conformity with the pattern of resource allocation established in (c), and finally (e) the consolidation and approval of the plans.

The L.P. model was the means of achieving the best solution to any particular problem, it was a great help in determining the robustness of the solution and was a guide in the search for profitable new management action.

The effect of these measures was to make the corporate planners not only responsible for the allocation of resources, which had always been the case, but also to give them more control over the process. The latter was new. Previously they had consolidated and pruned functional plans in a well-intentioned by misguided manner. Previously the plans were inconsistent, non-optimal and unachievable. With the new system, a rational and optimal allocation of resources is possible.

APPENDIX 4

THE PLANNING MODEL

CONTENTS

THE PLANNING MODEL

1. INTRODUCTION

I start this appendix with the mathematical formulation of the model. Besides the equations there is a brief description of the coefficients, bounds and so forth.

With section 3 begins a more detailed account of why I chose the particular formulation. The logical structure has been reversed in this manner to make the appendix easier to read for the person more concerned with the formulation than such things as design objectives and so on.

The formulation should be viewed in the context of the following scenario:

- sales,production and capacity available were all to be decision variables
- variables should be natural rather than composite
- overtime capacity should be linked to actual manpower
- there should be costs and limits on the rate of change of manpower.

This framework presents two difficulties. Firstly, there is no obvious right hand side (R.H.S.); all the usual candidates have been made into variables. Secondly, linking overtime to the output activity value of another variable looks as if it might involve a non-linearity.

2. THE FORMULATION

2.1. The Definitions

I define the variables:

S_{it}	sales of product i in period t	$i = 1,\ldots,9$
		$t = 1,\ldots,13$
P_{it}	production of product i in period t	
G_{kt}	production of product group k in period t	$k = 1,2$
I_{it}	inventory of product i in period t	
D_{jgt}	number of men in department j working capacity tranche q in period t	$j = 1,\ldots,8$ $q = 1,\ldots,4$
H_{jt}	number of men hired for department j at the start of period t	
F_{jt}	number of men leaving department j at the start of period t	
	The subscript m refers to a raw material in short supply.	

The usual conventions are followed:

a	for matrix coefficients
b	for R.H.S.
c	for objective function coefficients
z	for the value of the objective function
	Sometimes a variable name in brackets is used as a subscript to remove any possibility of confusion, e.g.

$b_{(S)it}$ distinguishes monthly sales of product i in period t from $b_{(P)it}$ the limit on production of product i in period t due to jigs and fixtures. Both are part of the R.H.S. vector.

2.2. The Equations

(a) sales restriction

$$S_{it} \leq b_{(S)it}$$

The actual sales must not be greater than forecast sales.

(b) production, sales, inventory identity

$$I_{i(t-1)} + P_{it} - S_{it} - I_{it} = 0$$

Opening inventory plus production equals sales plus closing inventory.

(c) production and capacity restriction

$$\sum_{j=1}^{8} \left(\sum_{i=1}^{9} a_{ij} P_{it} - \sum_{q=1}^{4} a_{jqt} D_{jqt} \leq 0 \right)$$

The capacity required must not be greater than the capacity available.

(d) product group identity

$$\Sigma P_{it} - G_{kt} = 0 \qquad \text{for } i = 1,2 \text{ and } k = 1$$
$$i = 3,4,5 \text{ and } k = 2 .$$

The production totals of certain groups of products are combined.

(e) material restriction

$$\sum_{t=1}^{13} \left(\sum_{i} \sum_{t=1}^{t} a_{mi} P_{it} \leq b_{mt} \right) \qquad \text{for } i = 8,9$$

The cumulative production of certain products must not exceed the cumulative deliveries of the material in short supply.

(f) rate of production restriction for individual products

$$P_{it} \leq b_{(P)it}$$

The level of production must not exceed the capacity of special purpose equipment.

(g) rate of production restriction for groups of products

$$G_{kt} \leq b_{kt}$$

The combined production of groups of products must not exceed the capacity of shared facilities.

(h) availability of overtime restriction

$$D_{jqt} - D_{j1t} \leq 0 \qquad \text{for } q = 2,3$$

The number of men on overtime must not exceed the number on normal time.

(i) hiring and firing identity

$$D_{jqt} - D_{jq(t-1)} - H_{jt} + F_{jt} = 0 \qquad q = 1$$

The difference between the number of men in a department in two consecutive periods equals the number hired minus the number fired.

(j) rate of hiring and firing restriction

$$H_{jt} - a_{(H)jt} D_{j(t-1)} \leq 0$$

$$F_{jt} - a_{(F)jt} D_{j(t-1)} \leq 0$$

The number of men hired (fired) from one period to the next must not exceed a certain percentage of the number of men in the department in the earlier period.

(k) facilities restriction

$$D_{jqt} \leq b_{jt} \qquad q = 1$$

The number of men in a department must not exceed the manning restriction of existing facilities.

(l) finished machines inventory restriction

$$I_{it} \geq b_{(I)it}$$

Inventory of each product must not be less than marketing's minimum requirement.

(m) the usual non-negativity restrictions

$S, P, G, I, D, H, F \geq 0$

(n) the objective function

$$\text{maximise } Z = \sum_{t=1}^{13} \left(\sum_{i=1}^{9} c_i S_{it} - \sum_{i=1}^{9} c_i P_{it} - \sum_{i=1}^{9} c_{it} I_{it} \right.$$
$$\left. - \sum_{j=1}^{8} \sum_{q=1}^{4} c_{jqt} D_{jqt} - \sum_{j=1}^{8} c_{jt} H_{jt} - \sum_{j=1}^{8} c_{jt} F_{jt} \right)$$

Table 4.1 below gives details of the units of the matrix coefficients, nature of the R.H.S. elements, and so forth.

COEFFICIENTS, R.H.S. & OBJECTIVE FUNCTION

(a) Coefficients

a_{ij} - standard hours per product per department corrected for spares and wastage

a_{jqt} - standard hours available per man for each tranche, department, month combination

a_{mi} - usage of material m on product i

$a_{(H)jt}$ - rate of hiring for each department

$a_{(F)jt}$ - rate of firing for each department

All other non-zero coefficients are 1. In the equations above, where a coefficient has not been explicitly stated it is understood to be 1.

Table 4.1 .../...

(b) R.H.S.

$b_{(S)it}$ - monthly sales volume

b_{mt} - cumulative delivery of material

$b_{(P)it}$ - jigs and fixtures restraint for individual products

b_{kt} - jigs and fixtures restraint for groups of products

b_{jt} - maximum size of department with existing facilities

$b_{(I)it}$ - minimum inventory holding

(c) Objective Function

$c_i S_{it}$ - sales revenue minus freight

$c_i P_{it}$ - direct variable cost minus freight and day-wage

$c_{it} I_{it}$ - inventory holding cost per period

$c_{jqt} D_{jqt}$ - cost of each tranche of capacity

$c_{jt} H_{jt}$ - cost of hiring one man

$c_{jt} F_{jt}$ - cost of firing one man

Table 4.1

2.3. Some Explanations

In this section I cover a few points which may not be immediately apparent from the equations and the coefficients, etc.

The introduction to this appendix contains the statement that there is no obvious R.H.S. And yet no less than 6 equations appear to have non-zero R.H.S.'s. The explanation concerns the facilities of the L.P. programme I used (MPS/360) and computational efficiency.

Any equation of the form

$$X_{pt} \leq b_{pt}$$

in which there is only one variable on the left hand side of the equation, and its coefficient is 1, can be omitted and the restriction accommodated by redefining the decision variable. This is known as the bounded variable technique; a brief description is given in Hillier and Lieberman. Fortunately there is no need for the user of the L.P. code, MPS/360, to do anything more than specify the bounds for a particular variable, the programme takes care of the rest with no disturbance to the intelligibility of the output. The motive for replacing equations with bounds is that computation time is very sensitive to the number of rows (it goes up as the square or the cube). If the matrix is large to begin with, these extra rows, repeated each time period, could make all the difference between low costs and quick turnround and high costs and long delays. The compromise was to express all the b_t's as bounds on variables except for the sales restriction in equation (a). This had the advantage of making it easy to do sensitivity analyses on the sales forecast via parametric programming of the R.H.S. .

The equations I wish to comment on are:

(a) sales restriction - the sales forecast need not be met. The two most likely reasons being that to do so would be infeasible or unprofitable.

(b) production, sales, inventory identity - by defining the equation to only span two consecutive months this avoids linking equations which run through the whole matrix. This makes it easy to maintain and modify the matrix.

(c) production and capacity restriction - capacity required (products) is defined as natural instead of composite variables. An example of the latter would be: the number of product p made in capacity tranche c in time period t By using non-cumulative natural variables, the amount produced each month can be read straight from the L.P. output listing without either differencing figures (required if cumulative variables had been used) or adding figures (required if composite product/tranche variables had been defined without an accumulating variable). Capacity available is defined as effective manpower; the coefficients being the capacity available per man for each tranche of capacity. The four tranches are linked together as an increasing piecewise linear function. The manner in which the tranches are linked so that the capacity available on overtime is related to the number of men assigned to work on normal time is covered in (h) below.

(e) material restriction - by dealing in cumulative units this equation permits the holding of raw material inventory without the definition of any variables.

(f) and (g) restrictions on rates of production - the inclusion of these variables and restrictions makes it possible to calculate directly the value to the company of further investment in special purpose equipment.

(h) availability of overtime restriction - the problem is to link the upper limit of one variable to the output value of another without getting involved with non-linearities and integar programming. As mentioned in (c), the trick is to work in capacity per man and limit the number of men working overtime to those on normal time. The diagram on the following page shows how this is achieved; see Exhibit 4.1.

(i) hiring and firing identity - this approach allows the costs of changes in the level of manpower to be included. If they were left out the model would (wrongly) always prefer to meet fluctuations in activity by changing the manpower level (if possible) rather than use any of the other possibilities, e.g. work overtime, subcontract, build up inventories, forego sales, etc.

ADDENDUM

Page 4.13, Exhibit 4.1

Suppose that instead of employing the maximum number of men possible, the optimum solution calls for a capacity in normal time of OA', the potential capacity at the two rates of overtime will be reduced to the dash lines A'B' and B'C'.

Thus, for a given department, OA is the maximum potential capacity available in normal time (with existing facilities) measured in standard hours. For the primary department in December OA is 30 * 364, AB is 30 * 64 and BC is 30 * 22; where 30 is the maximum number of men who can be fitted into the primary department without additional investment and 364 is the number of standard hours available per man on normal time. 64 and 22 are for the two rates of overtime (see page 7.37, table 7.15). Therefore the capacity available at "time-and-a-half", AB, is 17.5% of capacity available at normal time, OA.

Taking the example of the Factory Strike, the actual number of men assigned to the primary department in December is 25.53 (page 5.39 Exhibit 5.14 Number 384 Column DHTRTTNB). Consequently the amount of capacity available at "time-and-a-half" is 25.53 * 64 and not 30 * 64. The capacity available at the premium rates is therefore controlled to constant percentages of the capacity used at normal time, e.g. in December the capacity available at "time-and-a-half" is brought down from AB (1920 standard hours) to A'B' (1634 standard hours) as the capacity used on normal time is brought down from OA to OA'.

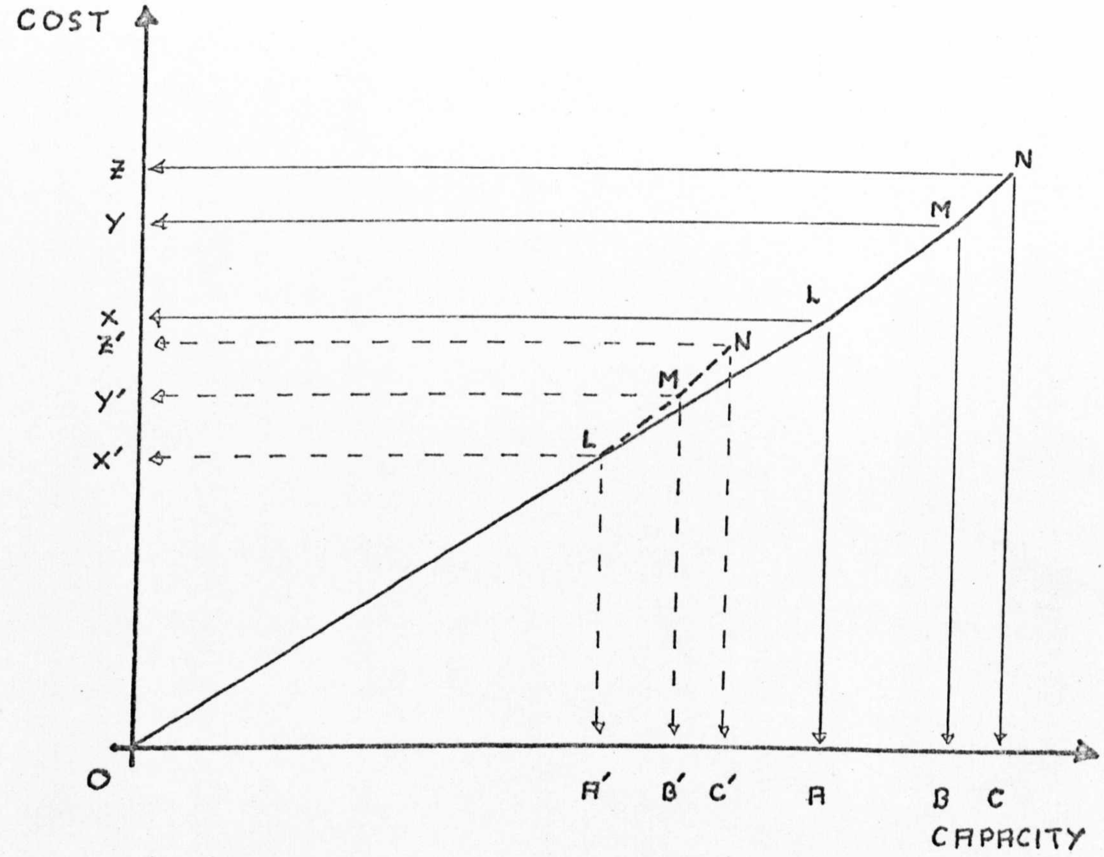
ERRATUM

Page 4.13, Exhibit 4.1

Reading from left to right, the first occurences of L,M,N, should read L',M',N'.

COST & SIZE OF CAPACITY TRANCHES

For a given department and period



The solid lines represent the relationship between cost and capacity if the maximum number of men, permitted by the existing facilities, is employed in the department. OA is the capacity available during the normal working week of 40 hours, AB the amount of overtime capacity at 'time-and-a-half' (17.5% of OA), BC at 'double-time' (6% of OA).

Suppose that instead of employing the maximum number of men possible, the optimum solution calls for a capacity in normal time of OA, the potential capacity at the two rates of overtime will be reduced to the dash lines A'B' and B'C'.

This approach works for two reasons. Firstly, the tranches of capacity are successively more expensive. Secondly, by making the units in which the tranches are measured 'output per man', it is simple to define an equation which says that the number of men assigned to each tranche of overtime must not be greater than the number of men assigned to work normal time.

Exhibit 4.1

(j) rate of hiring and firing restriction - the shadow prices associated with these restrictions will be a useful guide to different manpower policies.

(k) facilities restriction - machine loading is responsible for the upper limit on the number of men that can be employed in a department. This restriction enables the potential value of investment in general purpose equipment to be assessed.

2.4. Strengths and Weaknesses

As a summary of the first two sections of this appendix, I wish to mention some of the strengths and weaknesses of this method of formulating the problem.

2.4.1. Strengths

The advantages of the model are that:

- it is small and compact
- values of the important variables can be read from the L.P. code output
- the problems of maintaining or modifying the model are minimal
- it includes the most influential decision variables

2.4.2. Weaknesses

The shortcomings are due to the refinements which could have been made but were not because to have done so would proably have taken the model beyond the threshold of change to which the company could adapt.

- the nightshift could be defined as separate variables instead of being included with the dayshift
- the cost of investing in new facilities could be included either as a linear or non-linear restriction
- the model could be integrated with a financial accounting module, as described by Mao
- the use of integer programming would enable the model to analyse either/or situations, such as sourcing, more realistically.

2.4.3. Matrix Structure

To give an idea of the way the non-zero coefficients are distributed and the recurring patterns in a multi-period model, I have included a print-out of the first two periods of the model in Exhibit 4.2 on the next page. Unit coefficients are printed as 1, all other non-zero coefficients are represented by an asterisk, zero coefficients are left blank.

An explanation of row and variable names is given in Appendix 8.

It can be seen that my policy of defining natural variables and reluctance to condense the matrix in the interests of interpreting the output has resulted in a relatively sparse matrix. In fact, the structural

		PFWDTRIZ	PTRALRIZ	PLOADRIZ	PDIGGRIZ	PFWDTRPA	PTRALRPA	PLOADRPA	PDIGGRPA	MFWDTRPA	MTRALRPA	MLOADRPA	MDIGGRPA	PFWDTRIA	PTRALRIA	PLOADRIA	PDIGGRIA	DHTRTTNA	DHTRTTXA	DHTRTTZA	DHTRTTSA	DWELDGNA	DWELDGXA	DWELDGZA	DWELDGSA	DASSLYNA	DASSLYXA	DASSLYZA	DASSLYSA	PFWDTRPB	PTRALRPB	PLOADRPB	PDIGGRPB	MFWDTRPB	MTRALRPB	MLOADRPB	MDIGGRPB	PFWDTRIB	PTRALRIB	PLOADRIB	PDIGGRIB	DHTRTTNB	DHTRTTXB	DHTRTTZB	DHTRTTSB	DWELDGNB	DWELDGXB	DWELDGZB	DWELDGSB	DASSLYNB	DASSLYXB	DASSLYZB	DASSLYSB	DHTRTTUB	DWELDGUB	DASSLYUB	DHTRTTDB	DWELDGDB	DASSLYDB	RHS1
LOWER BOUND		*	*	*	*													*				*				*																																		
UPPER BOUND		*	*	*	*	*	*	*	*									*				*				*				*	*	*	*									*				*				*										
SHTRTMTA	L					*	*	*	*									-*	-*	-*	-*																																							
SWELDNGA	L					*	*	*	*													-*	-*	-*	-*																																			
SASSMLYA	L					*	*	*	*																	-*	-*	-*	-*																															
SHTRTTXA	L																	-1	1																																									
SWELDGXA	L																					-1	1																																					
SASSLYXA	L																									-1	1																																	
SHTRTTZA	L																		-1	1																																								
SWELDGZA	L																						-1	1																																				
SASSLYZA	L																										-1	1																																
SHYDRAMA	L						1	1																																																				*
SFWDTMSA	E	1				1				-1				-1																																														
STRALMSA	E		1				1				-1				-1																																													
SLOADMSA	E			1				1				-1				-1																																												
SDIGGMSA	E				1				1				-1				-1																																											
SFWDTPSA	L									1																																																		*
STRALPSA	L										1																																																	*
SLOADPSA	L											1																																																*
SDIGGPSA	L												1																																															*
SHTRTMTB	L																													*	*	*	*									-*	-*	-*	-*															
SWELDNGB	L																													*	*	*	*													-*	-*	-*	-*											
SASSMLYB	L																													*	*	*	*																	-*	-*	-*	-*							
SHTRTTXB	L																																									-1	1																	
SWELDGXB	L																																													-1	1													
SASSLYXB	L																																																	-1	1									
SHTRTTZB	L																																										-1	1																
SWELDGZB	L																																														-1	1												
SASSLYZB	L																																																		-1	1								
SHYDRAMB	L						1	1																							1	1																												*
SFWDTMSB	E													1																1				-1				-1																						
STRALMSB	E														1																1				-1				-1																					
SLOADMSB	E															1																1				-1				-1																				
SDIGGMSB	E																1																1				-1				-1																			
SFWDTPSB	L																																	1																										*
STRALPSB	L																																		1																									*
SLOADPSB	L																																			1																								*
SDIGGPSB	L																																				1																							*
SHTRTTCB	E																	1																								-1												1			-1			
SWELDGCB	E																					1																								-1									1			-1		
SASSLYCB	E																									1																								-1						1			-1	
SHTRTTUB	G																	*																																				-1						
SWELDGUB	G																					*																																	-1					
SASSLYUB	G																									*																														-1				
SHTRTTDB	G																	*																																							-1			
SWELDGDB	G																					*																																				-1		
SASSLYDB	G																									*																																	-1	

Exhibit 4.2

density is 0.75, with an m x n matrix (a_{ij}) the calculation is:

$$\text{density} = \frac{\text{count of non-zero } a_{ij}\text{'s}}{mn}$$

Gross density adds the non-zero elements of the logical vectors and divides by $m(m + n)$.

Exhibit 4.3 shows a summary of the magnitude of the matrix coefficients. MPS/360 has an optional procedure to scale the input data. I used this procedure rather than scale the data manually prior to input.

SUMMARY OF MATRIX COEFFICIENTS

PLANNING BASE

SUMMARY OF MATRIX

SYMBOL	RANGE			COUNT (INCL.RHS)
Z	LESS	THAN	.000001	
Y	.000001	THRU	.000009	
X	.000010		.000099	
W	.000100		.000999	
V	.001000		.009999	2
U	.010000		.C99999	3
T	.100000		.S99999	1
1	1.000000		1.000000	88
A	1.000001		10.000000	1
B	10.000001		100.000000	36
C	100.000001		1,000.C00000	21
D	1,000.000001		10,000.000000	
E	10,000.000001		100,000.000000	
F	100,000.000001		1,000,000.000000	
G	GREATER	THAN	1,000,000.C00000	

Exhibit 4.3

3. BACKGROUND TO MODEL FORMULATION

The situation which the model was to represent had a number of characteristics which although typical, I believe, of manufacturing industry, could not be adequately described by existing formulations. Consequently, the model I developed for the corporate planning problem had several interesting features:

- contrary to the usual production smoothing or assignment problems, capacity available was a decision variable instead of a R.H.S.
- sales were also treated as variables
- the objective was maximization
- the sales mix and production mix problems were solved simultaneously
- the different tranches of capacity within a given department/ month combination were described as interdependent segments of an increasing piecewise linear function
- the number of men working overtime was limited to those assigned to the regular payroll
- the marginal cost of production did not assume a linear relationship between the direct labour hours of a product and the cost of supplying the hours
- management was able to evaluate the consequences of having men on short-time
- unprofitable sales were dropped (marginal revenue less than marginal cost).

4. DESIGN OBJECTIVES

There were certain criteria which if met would increase the chances of the model being accepted and used. The objectives concerned: construction, maintenance, performance and results.

4.1. Construction

The model should be as small as possible consistent with producing valuable results, because (a) refinements could follow later having once gained management's confidence and approval, (b) the promise of jam tomorrow would not long sustain top management's enthusiasm for a project they considered speculative, (c) the data deck should be capable of manipulation by hand, and (d) computer runs required a dedicated machine which was expensive as well as difficult to schedule.

Variable names should be standardised in length and easily recognisable mnemonics in order to ease the interpretation of output, the flagging and masking of variables and the subsequent writing of a report generation programme.

The matrix should not be condensed if this involved either adding more than 6 non-zero matrix elements for each reduction in the number of rows or making it necessary to perform auxiliary calculations on the output to derive the activity values of decision variables.

Since the sales of many of the products had a pronounced seasonal pattern (e.g. seed drills), (a) the basic unit of time should reflect the scheduling and resource allocation problems this presented, and (b) the model should span more than one complete cycle, i.e. 13 months.

4.2. Maintenance

Maintenance of the model would consist not just in updating the matrix coefficients as new estimates became available once a year, but also in adding new and deleting old time periods as the year unfolded. It was envisaged that the model would be maintained on a rolling 13 month basis. At least one monthly run would be needed to evaluate the consequences of the monthly revisions of the sales forecast.

Some of the problems of maintaining the model would be mitigated by a matrix generation programme which processed the raw data into the form required by the formulation and the L.P. code. The original project proposed to M-F had provision for a matrix generator, but it was low down on the list of priorities. Initially the model was to be run without its help.

There should be no linking equations which crossed more than one time period boundary. This does not usually decrease the number of rows and variables but it does mean a big saving in non-zero coefficients. Another advantage would be that adding and deleting months would only involve operations on the two ends of the data deck; there would be no sorting and sequencing problems in the middle.

The variables should be grouped by type within time period instead of vice versa. This would make possible the addition and deletion of months by blocks without reducing the ease with which new products or plants could be introduced. There are arguments in favour of increasing the length of a unit of time, say from one month to three after the first six months of the planning horizon. The reasons are that the uncertainty in the estimates does not justify a finer analysis, and that for any given length of planning period the model is smaller. The trouble with aggregation is that it hides the problems (average demand may be within average capacity), it increases the calculations and keypunching necessary for updating (as three month blocks are broken down) and the length of the planning horizon is constantly changing. I think that the disadvantages of aggregation are greater than the advantages.

4.3. Performance

The process of debugging and optimising a large model can be difficult. If possible the model should be designed to reduce the chances of going infeasible.

An efficiently run computer centre is unsympathetic to inaccurate estimates of run time. Unfortunately the answer is not to give oneself an ample margin of error, this strategy merely lowers the L.P.'s priority in the queue of waiting jobs.

If the solution is infeasible it inevitably occurs in the last few moments of a run, sometimes having performed a lengthy search for the illusive basic feasible solution. The consequences are (a) a time-consuming search to find and correct the cause of the infeasibility, (b) no results, and (c) a delay before getting another computer run.

There are two strategies, not mutually exclusive, for reducing the risk of infeasibility. The first is to create overspill variables with high cost penalties so that they are only used as a last resort; an example would be the provision of unlimited subcontract capacity. The second is to have a maximising model with 'less-than-or-equal-to' constraints for the main demands for resources instead of a cost minimisation model with the opposite constraints.

There are two additional reasons for a maximising model with sales as a decision variable: (a) the model can assign values to demands for resources (up to a specified limit) and thereby refuse the unprofitable sale, and (b) where a cost minimisation model would go infeasible, leaving the analyst to select the restraint to be relaxed, the maximisation model automatically drops the right number of sales and production units of the marginal product(s). The latter point is perhaps more substantial than it might appear. The problem to be solved is the selection of both the variable(s) and/or restraint(s) to be changed and the amount(s) by which it/they should be changed. The shadow price by itself or in conjunction with the company net return (not input to the model) is not much help. Information on the range over which the shadow price is valid is only available after the optimal solution has been reached, as a result of using a post-optimal procedure. It can be seen that the elimination of infeasibilities from a minimisation model can be difficult.

4.4. Results

It was anticipated that the model would be run in response to four types of demand:

- to evaluate the consequences of the revised sales forecast, which was produced monthly
- to help establish the pattern of resource allocation and the detailed plans for the coming fiscal year
- to supply data to the financial analysis department on the consequences and vulnerabilities of proposed sourcing and cut-in dates of new products
- to provide reliable quantitative data to help resolve inter-functional disagreements.

Since the model was to be used frequently, for a number of different purposes and, initially at least, without a report writing programme, the variable names should be meaningful, the variables natural rather than compound and post-optimal manual calculations be kept to a minimum.

In other words, it should be easy to recognise the variables and to interpret and analyse the results.

5. VARIABLES AND RESTRICTIONS

E. M. L. Beale in his book 'Mathematical Programming in Practice' suggests that 'One should shart by formulating and running a one time period model'. This is good general advice to help identify the key variables in a novel situation, but it was not the appropriate initial step for the model of B.D.R.

One of the main headaches of planning at M-F was the seasonal fluctuation in sales, and the consequences this had for the scheduling of men and the provision of facilities.

The effect of the fluctuations would be masked by a single time period model in which the variables represented aggregate demands for products and supply of resources. The question was not whether to build a multi-period model, but what unit of time was necessary to capture the behaviour and complications of the real world.

A suitable compromise between size of model, degree of detail, availability of data, length of planning horizon and requirement for output reports, was to choose a time unit of one month. The only restriction which did not fit easily into this framework was that on the maximum daily rate of production. Otherwise it was possible to establish suitable relationships between some of the more obvious variables.

The next stage was to experiment with different combinations of suspected key variables to discover those critical for the model to replicate the behaviour of the real system. One of the difficulties of model construction was the discrepancy between local management's perception of the system and the way it actually worked. Fortunately this tended to modify the relationships between the variables rather than their selection.

One class of decision variables which will not be discussed specifically under either demands for or supplies of resources is the production variables - the quantity of each product produced during each period of the planning horizon. The reason for this is that I regard sales as the demand for resources, and they are defined as decision variables, instead of being part of the R.H.S.

In this scheme, production is an intermediary between resource inputs and sales, and production variables are defined as combinations of resource inputs.

There is one type of restriction specifically associated with the production variables: the limit on the number of each product and some groups of products which can be produced in any given period. The limit is due to the capacity of special purpose equipment (often jigs and fixtures), some of it used for individual products, some common to a family of products. In the latter case it is necessary to define a variable for the combined production of the products which share special purpose equipment.

5.1. Demands for Resources

5.1.1. Sales

In this section I consider the reasons for making sales a class of decision variables instead of the more usual R.H.S.

In a manufacturing and selling company such as M-F, the demands for all the main resources are generated by the sales forecast for existing and new products, which is why traditional planning starts at that point rather than any other.

However, there is no overriding reason why the sales forecast should be met for all products, thus viewing the sales forecast as an exogenous variable. Occasionally a company will continue with an unprofitable product to maintain a foothold in the market while a replacement is being developed. Alternatively, an unexpected order might be squeezed in to the production schedule for a loyal customer even though this generates high disruption costs or even temporary losses. But these should be the exceptions rather than the rule.

The problem with the traditional approach is that the sales forecast is accepted or not on the grounds of whether it is possible to make the products instead of whether it is profitable. The diagram on the following page outlines the process. This approach is illustrated very well by what happened at M-F when the sales forecast could not be met: the marketing department 'went on allocation' and accepted whatever products the factory could supply - marketing then rationed their customers. At no stage in the process was any attempt made to work out the most profitable sales and production mix. This was due to the quarrel being regarded as a family affair between marketing and production, neither of whom were directly concerned with profits, and even if they had been there was no means of performing the calculations.

Apart from making it less likely that the model is infeasible, there are several reasons for treating the sales forecast as a variable rather than the more usual R.H.S.

TRADITIONAL SALES & PRODUCTION PLANNING

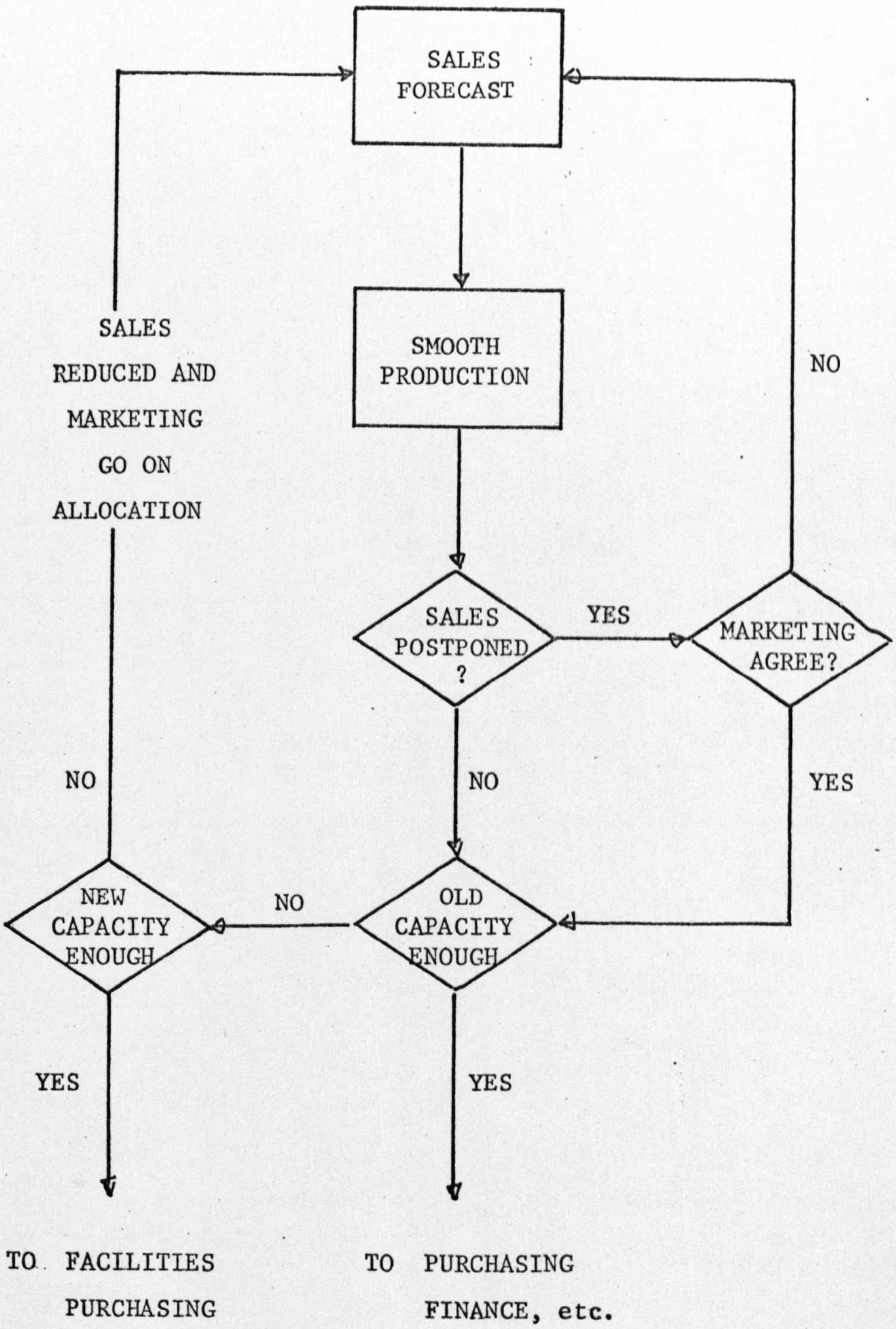


Exhibit 4.4

- It permits profit maximisation in place of cost minimisation, thereby removing the need for post-optimal manual calculations .
- It solves simultaneously the production mix and sales mix problems .
- The marginal sales are automatically dropped, i.e. marginal revenue is greater than or equal to marginal cost. In so doing the model selects the products, the number of units and the months. The benefit of getting the model to perform this task is best appreciated by attempting to replicate it manually. The number of possible variations is large and for each the steps in the process would involve:
  - the addition or deletion of sales or capacity to derive the new figure for total cost
  - the manual calculation of revenue
  - the subtraction of total costs from total revenue to give the new profit
  - the subtraction of the old profit from the new to discover the marginal effect of the particular change
- the shadow prices and marginal costs are easily interpreted to identify the most profitable avenues for new management action.

5.1.2. Finished Machines Inventory

Finished Machines Inventory (F.M.I. or inventory) is held by marketing as a hedge against the unexpected order and the factory's inability to meet the promised production schedule. Inventory is also held by the factory to help smooth production.

The inventory requested by marketing is a demand for resources, while the factory's holding is a source of stored capacity.

The finished machines inventory policy of marketing, expressed in minimum values per product per month, is properly regarded as a decision variable contributing to the demand for resources.

5.2. Supplies of Resources

Exhibit 4.5 on page 4.31 lists the demands for and supplies of resources.

The main categories of resource are: manpower, subcontract, inventory, materials, money and facilities. The contribution of the first five is relatively easy to measure and define. The amount of productive equipment required for the manufacture of one unit of product is more difficult to determine. The corollary of the last point is that whereas it is simple to breakdown a production schedule into manpower plans, supplier schedules and cash flow, it is another matter to decide whether the capacity on the 500 ton brake press will be sufficient.

I discuss each of the resources in turn.

5.2.1. Manpower

B.D.R. has 7 productive departments, each corresponding to a different manufacturing activity: press shop, machine shop, etc. Because

L.P. INPUTS & OUTPUTS

INPUTS

RESOURCES

Demands

Sales Forecast

Inventory Requirements

Supplies

Opening Manpower

Overtime restriction

Subonctract

Opening Inventory

Materials Restriction

Financial Objective

Facilities Restriction

CORPORATE
L.P. MODEL

OUTPUT

Sales Mix

Production Schedule

Manpower Schedule

Overtime Plan

Subcontracting Requirement

Monthly Inventory - Sales

- Smoothing

Materials

Facilities Plan

Financial Optimum

Exhibit 4.5

each department requires a different type of skill, there is mobility of labour within departments but not between. So manpower is not a single homogeneous resource but 7 distinct resources. Consequently it is not sufficient to smooth the total demand for manpower, the load in each department must be smoothed.

The only exception to the mobility of labour within departments is in the assembly area. This department is split into two sections, one for F.E., the other for I.C.M., and there is no mobility between the sections. Each must be loaded and smoothed individually. The effective number of departments is therefore 8. Dividing the machine shop makes it 9.

The factory works two shifts and there are two rates of overtime. The details are given in Appendix 7 on data collection.

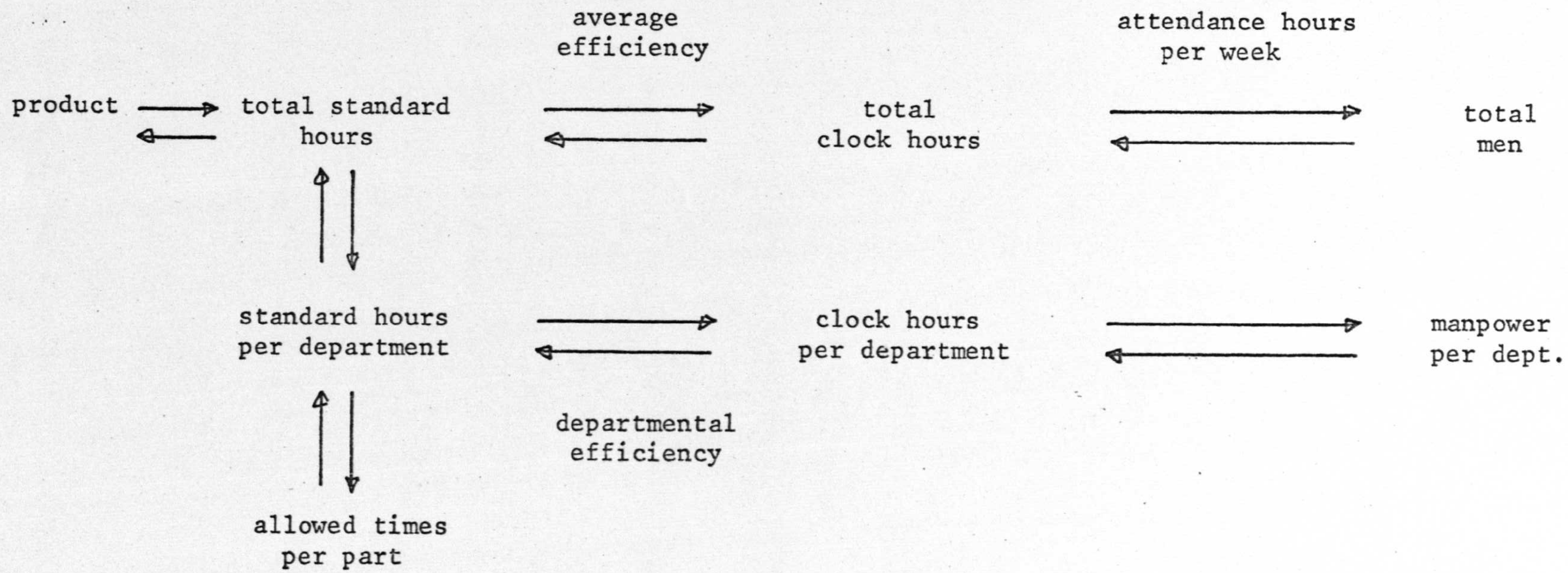
The labour content of a product is measured in standard hours (determined by time study and used for scheduling production and paying labour) and is split out by productive department. A correction factor for efficiency makes it possible to turn standard hours into the equivalent number of man hours. In this way various relationships are established, some of which are illustrated on the following page, see Exhibit 4.6.

For a number of reasons, capacity available should be a variable instead of a R.H.S.:

- In the medium term manpower levels can be changed (hiring and natural wastage). There are limits restricting the rate of change and costs associated with units of change. Parametric programming is no substitute in this situation.
- If capacity available is part of the R.H.S., the costs of direct labour have to be put against the products. The effect

Exhibit 4.6

RELATIONSHIPS BETWEEN PRODUCTS AND MANPOWER



is to mis-state the marginal cost of making an extra unit of product, and to omit certain costs which vary directly with manpower but not with production, e.g. holiday pay, canteen subsidy. These last two points are elaborated in Appendix 7 on data conversion.

- The consequences of having unused capacity can only be assessed if capacity available is a variable (unless the L.P. code allows prices to be put against slack variables).
- When capacity available is a R.H.S. separate (composite) variables must be defined for each product made in each tranche of capacity, i.e. normal time, overtime, etc. in order to include the premiums associated with successive tranches. In multi-time period models this involves many variables.
- With composite product/capacity tranche variables, as soon as the normal capacity of one department is used up, all departments move into overtime working. Implying that, for instance, the press shop is working Saturday overtime even though it has spare capacity during the week.
- The potential size of a department in one period is related to its actual size, and not its potential size, in the previous period. This relationship cannot be expressed if capacity is a R.H.S.
- In a similar vein; the overtime capacity is linked to the actual number of men in a department, not the potential number. Again, parametric programming is little help. To illustrate:

if the actual manpower used is 25 and the potential 30, the maximum overtime available is 250 hours per week (25%), not 300.

. Only by defining sources of capacity as variables with associated costs is the model able to choose the cheapest combination of productive resources.

One other source of capacity is subcontracting. I mention it here because it is closely related to departmental manpower. Operations are put out to subcontract to relieve the workload on an individual department. An anomaly of the old system of production control was that the amount of work planned for subcontracting was kept at 5% throughout the year, while there was (a) spare overtime capacity, and (b) spare facilities and equipment.

To summarise the restrictions associated with manpower:

. There was an upper limit to the number of men that could be employed in each department with existing facilities.

. There were restrictions for each department on the rate of change of manpower from one month to the next. Upwards, the limit was imposed by the need to train and assimilate the new men. Downwards, the restriction was due to industrial relations problems which limited reductions to natural wastage.

. There was a cost associated with changes in manpower levels. Upwards, they were primarily advertising, training and free clothing. Downwards, the cost was administrative.

These relationships could only be expressed by making capacity available a decision variable.

5.2.2. Finished Machines Inventory

In 5.1.2. I mentioned that inventory is carried for two purposes, both as a demand for and supply of resources. The factory uses inventory as a source of stored capacity. It is one of the means of ironing out fluctuations in production and at the same time meeting the demand for products from marketing.

It is not necessary to define two inventory variables, for every product/month combination, one for each purpose - the two uses can be accommodated by a single variable.

The amount of inventory required by the factory is established by running the model with no restriction on the level of inventory other than the usual non-negativity constraint. This gives an 'evaluation base' with which the effects of other policies may be compared.

The results of subsequent runs with different inventory policies, either upper or lower bounds, can be set against those of the evaluation base and the differences computed. Examples of an evaluation base and inventory policy runs are shown in Appendix 6 on using the model.

5.2.3. Materials

There is no need to define as a variable in the model any material which is in abundant supply. In this case the process of calculating the quantities and negotiating deliveries is irrelevant to resource allocation. The only factor of interest is the cost, and this is one component of the direct variable cost of each product.

There are two circumstances in which it may be necessary to include a particular material as a variable or just as an equation. The only condition is that it must be possible to specify the amount of it required by different products.

The first is when the material is expensive and, for some reason, significant stocks are held. In this situation it may be advisable to keep track of movements into and out of the stock and include the holding cost in the objective function.

The second is when a particular material is in short supply and restricting production. Here the delivery schedule is important. Also it is desirable to allow the model to choose which of the products competing for this particular resource should have priority. There is an example of a hydraulic ram limiting production in Appendix 6 on using the model.

5.2.4. Money

The objective of a company is usually taken to be the maximisation of profits or the minimisation of costs. In either case the resource of money is included in the model as the objective function; one of the coefficients associated with decision variables.

Therefore there is no need to include financial variables in the model unless there are specific financial constraints. An example would be the requirement to reduce or maintain the overdraft at a specified level. This would require the definition of a variable for the cumulative cash flow to the end of each month. The coefficients relating it to the other decision variables would depend on the giving and receiving of credit and the assumptions governing the payment of other expenses.

Another type of financial constraint would be to say that the opportunity cost of funds was x% per annum. In this case, the monthly receipts and payments in the objective function should be multiplied by the appropriate discount factors to give the corresponding present value. The effect of such an approach would be to place greater emphasis on present sales compared with future ones, and vice versa for costs.

Having constructed the basic resource allocation model without these two specific financial constraints, it would be easy to include either or both. Neither were included in the model for M-F.

5.2.5. Facilities

Facilities and equipment are relevant to resource allocation in three ways: the utilization and disposal of existing capacity and the provision of new. The inclusion of these restrictions in the M-F model depends on it being legitimate to express the capacity of a piece of equipment in standard hours.

I think it is legitimate for the reasons that (a) the departmental efficiency (standard hour performance) in part reflects the capital intensity of production methods (130% in the heat treat department, and 250% in the paint), and (b) no assumption is involved which is not implicit in the calculation of standard hours per product per department (the latter are aggregates of 'floor to floor' times of individual operations).

One possible complication is if the capital intensity of production methods varies widely within a department; for example, suppose the machine shop had both radial arm drills and numerically controlled equipment. In this situation it would be necessary to split the department into homogeneous machine groups with separate efficiency factors. This strategy was employed for the machine shop at B.D.R., which contained two groups of equipment, one for flow-line production, the other for batch production. The former had an efficiency of 220% and the latter 200%. There was mobility of labour between the two groups of machines.

With these introductory comments in mind, I go on to consider facilities and equipment as a resource input.

The limit imposed on production capacity by the existing facilities can be expressed as an upper limit on the number of men that can be employed in each department. This is simpler than the alternative of having a separate variable for machine capacity, and just as effective.

A similar approach can be applied to additions to capacity. In other words, the effect is to increase the number of men that can be employed. The investment in the new capacity (a setup cost) would not be included in the model, and the return on investment would be calculated from the difference in profits with and without the extra capacity.

Just as it is possible to define a variable for existing capacity in each department, a similar method could be used for new capacity. The only assumption being that new capacity is infinitely divisible. It could be argued that this assumption is not inappropriate for the medium term planning of a large job shop. On the other hand, it could be got round by using integer programming, but this is an unnecessarily expensive alternative.

For an initial formulation, I do not think that the benefits justify including facilities as a separate class of variables in the model. The restriction they impose on production can be included indirectly.

5.2.6. Summary of Variables and Restrictions

This section consists of a list of the classes of variables and one or two of the facts mentioned previously.

Production	-	daily rates of production
Sales	-	marginal revenue $\geq$ marginal cost
Manpower	-	rates and costs of changes
Overtime	-	linked to manpower, also premiums
Subcontract	-	overspill capacity
Inventory	-	limit imposed by inventory policy
	-	required for production smoothing
Materials	-	limit production levels
Facilities	-	limits on existing size of departments
	-	limits and costs on additions

APPENDIX 5

RESULTS

CONTENTS

List of Exhibits

Page No.

RESULTS

1. INTRODUCTION

On December 16th, 1971 the Assistant Managing Director of M-F U.K., Mr. Smith, at the close of a meeting to review the research project, decided that the Tactical Planning Model should be used by top management to assist with the tactical and strategic policy issues. He made Mr. Bevan, his personal assistant, responsible for the implementation of the existing model and for exploring the possibilities of extending the approach to the rest of the U.K. operations. To this end I was to work with Mr. Bevan.

My specific role was to document the project and to provide operating instructionsfor the management information services (M.I.S.) department on how to maintain the program and run the computer. The reason for the latter was that, at that time, I was the only person in the U.K. company with experience of operating the computer in the O.S. mode required by MPS/360. The experience covered both the software and driving the computer. In other words, during the development of the project, I had been the sole interface between user and computer, and therefore responsible for:

- model construction and maintenance
- linear programming
- MPS/360 - program
- O.S./360 - software
- machine operation
- programming.

The last four alone involved being familiar with 15 IBM manuals. Implementation required me to document these tasks and assign them to the relevant functions. I am currently engaged in these activities, but no longer as an employee of M-F. The reasons are as follows.

During November 1971 a new computer had been delivered. Bedding-down problems necessitated M-F at first having to put work out to bureaus and subsequently having to reinstall the old computer. Associated with the new computer were a number of ambitious projects to rationalise computing facilities throughout the U.K. It was estimated that it would be 6-9 months before the computer facilities were operating efficiently enough to give time to the implementation of the Tactical Planning Model.

In these circumstances, I decided to leave the company at the end of January 1972 to write my thesis and to document model construction and maintenance. I agreed to become directly involved again when the situation was more favourable. The appendices on data, model construction, etc. will be used as the first level of documentation for M-F.

The first stage of implementation concerns the B.D.R. factory and from the cost/benefit analysis in section 2 can be seen to require only part of the attention of one analyst. The second stage, extension to the whole of M-F U.K., would involve the creation of a planning department responsible to the assistant managing director (distinct from the existing financial planning department) and a reorganisation of the planning cycle and systems as outlined in Appendix 3. It follows that my suggestions for reorganisation and new procedures, being the second stage of implementation, are the main non-descriptive elements of my thesis. They represent what I think is involved in widening the project to include the rest of the U.K. operations.

Because computer time is expensive, and because mere size adds nothing to either the description or the demonstration of the model, the computer output in my thesis is taken from a scaled down model, which retains the complexity of the original. However, the cost/benefit analysis relates to the original model and was presented to M-F.

2. COST BENEFIT

The analysis, Exhibit 5.1, is based on the project implementation plan shown in Exhibit 5.2. No mention is made of development costs. This is because the main development costs were manpower and computer time. The former was covered by an S.S.R.C. grant. The cost to M-F of computer time was insignificant as the marginal expenses were electricity and paper: the machine was leased, there was spare capacity and my time was free.

COST/BENEFIT ANALYSIS

SYSTEM COSTS

Implementation Costs

		£	£
(i)	Machine Time		
	3 hours program testing		
	2 hours system testing		
	5 hours at £80 per hour		400
(ii)	Manpower Requirements		
	1 Systems Analyst, 7 man weeks at £2,200 p.a.	300	
	3 Computer Programmers, 15 man weeks at £2,000 p.a.	580	
	1 Project Manager, 10 man weeks at £2,000 p.a.	390	
	1 Project Analyst, 10 man weeks at £2,000 p.a.	390	1,660
(iii)	Training Costs for Project Analyst		
	L.P. Formulation course - 3 days	30	
	MPS/360 Introduction course - 1 1/2 days	15	
	MPS/360 Implementation course - 1 week	56	
	Computer experience time - 4 hours	320	421
			2,481

Annual Running Costs

			£
(i)	Machine Time - Monthly		
	. delete and revise data	- 1/4 hour	
	. first solution of new model	- 1 hour	
	. 2 policy runs	- 3/4 hour	
		2 hours	
	24 hours p.a. at £80 per hour		1,920

Exhibit 5.1

.../...

	£	£
(ii) Machine Time - Annually		
. 1 initial solution to update the model - 1 hour		80
(iii) 1 Project Analyst for 25% at £2,000 p.a.		500
		2,500

TANGIBLE BENEFITS

Subcontract Premiums	60,000

PAYBACK

The Implementation and first year running costs are covered two times by projected first year savings

NOTES

The programmes change the system from being card-based to disk-based. Three programmes are required:

- validation routines
- coefficient generator
- merge

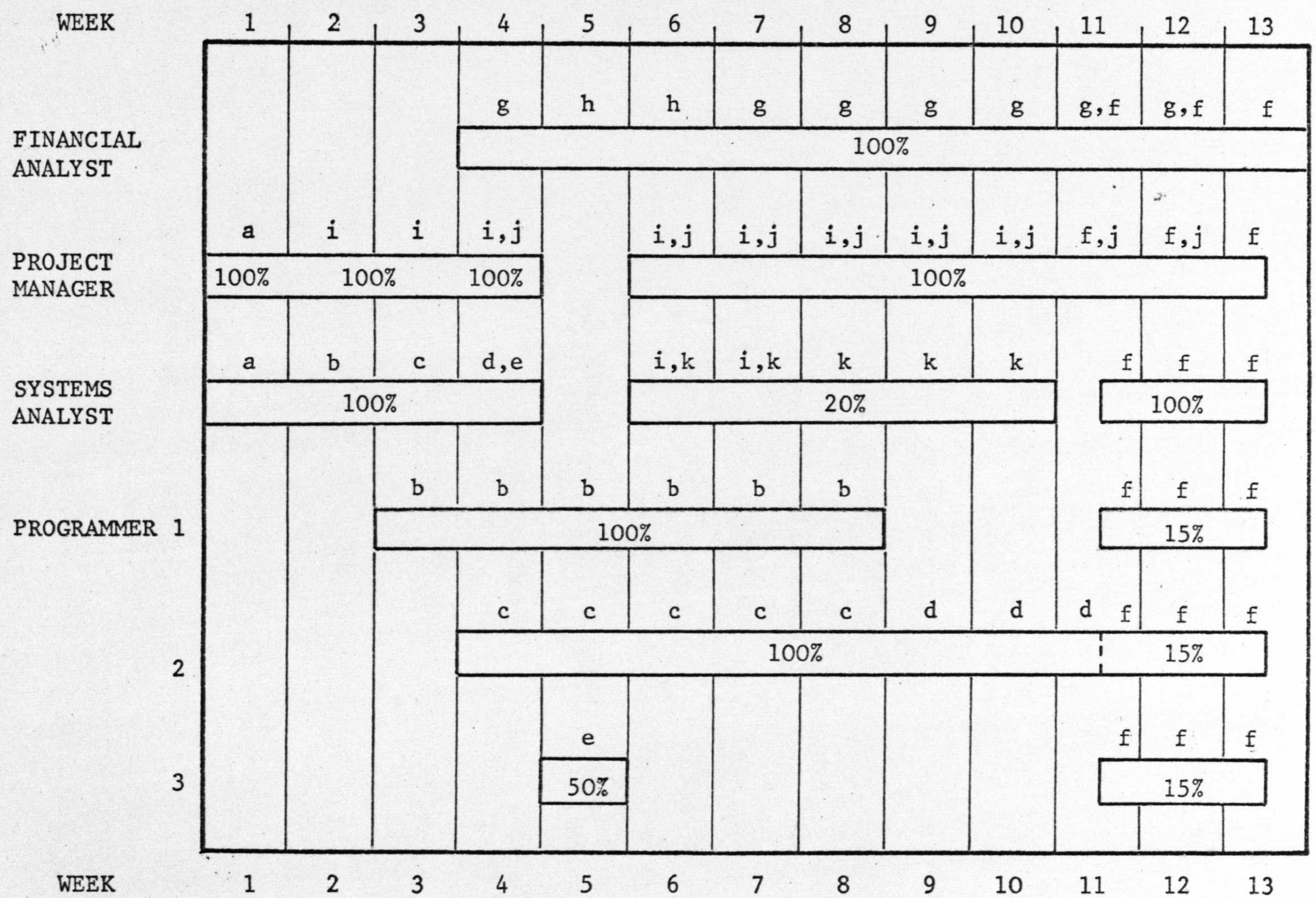
The flow-chart for the system is given in Exhibit 5.3. The usual IBM flowcharting conventions are used. The programmes to be written are marked:

V C M

Exhibit 5.1

Exhibit 5.2

IMPLEMENTATION PLAN



KEY TO ACTIVITIES

a Systems Investigation

b Validate Input Program

c Calculate Coefficients Program

d Merge Input Data Program

e Customise MPS for disk input

f Systems Testing

g Familiarisation with Project

h Attenance at Courses

i Documentation

j Instruction of Financial Analyst

k Monitor Programming Progress

FLOW CHART FOR PLANNING SYSTEM

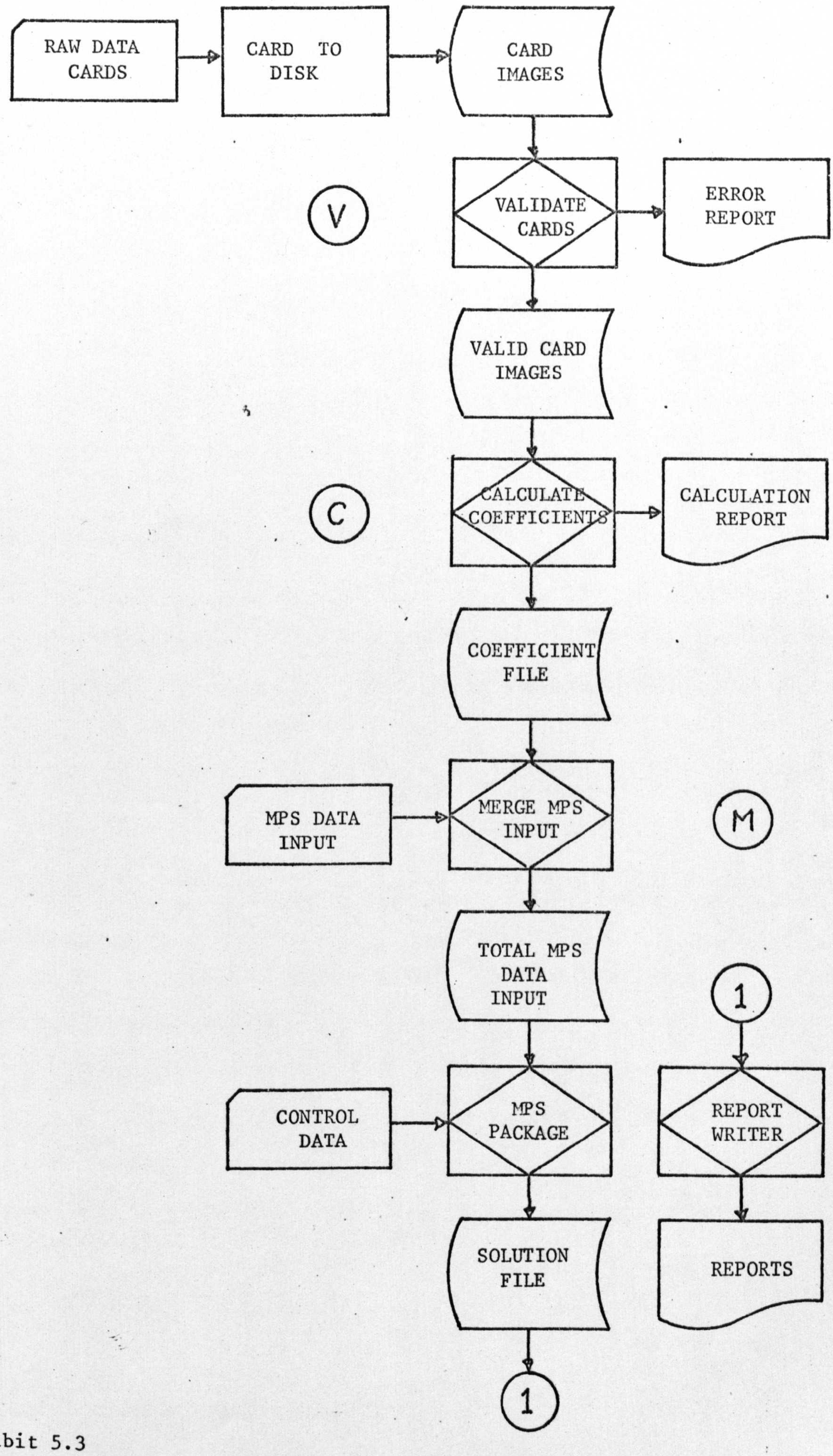


Exhibit 5.3

3. OUTPUT

There are three types of output I wish to illustrate and discuss: the one-page summary, the full optimal solution, the post-optimal results.

The structure is to start with observations about and conclusions from the three types of output and then to describe and explain them. Apart from the one-page summary, the examples of output are with the relevant section on description.

3.1. One-Page Summary

The summary is reproduced as Exhibit 5.4; a listing of the program which generated the report can be found in Appendix 8 on constructing and running the model.

The report is divided into four sections: headings, financial summary, activity summary and sales summary. The financial summary gives details of the more volatile elements (premiums etc.) of the line COST; the line LOST SALES REV. assumes that a postponed sale is a lost sale. The activity summary is split between standard hours and men.

The diagram, Exhibit 5.5, presents the main details graphically and gives a clearer idea of what is happening in general terms. The translucent corrects for the different number of days in the periods.

Briefly, in-house facilities are increased at the maximum rate until February in order to meet sales in those months and build up sufficient inventory for sales in March. Work is subcontracted mainly for the secondary department and to a lesser extent for the primary.

Exhibit 5.4

REPORT FOR M.D.

I MANAGEMENT POLICY:FACTORY STRIKE IN MARCH

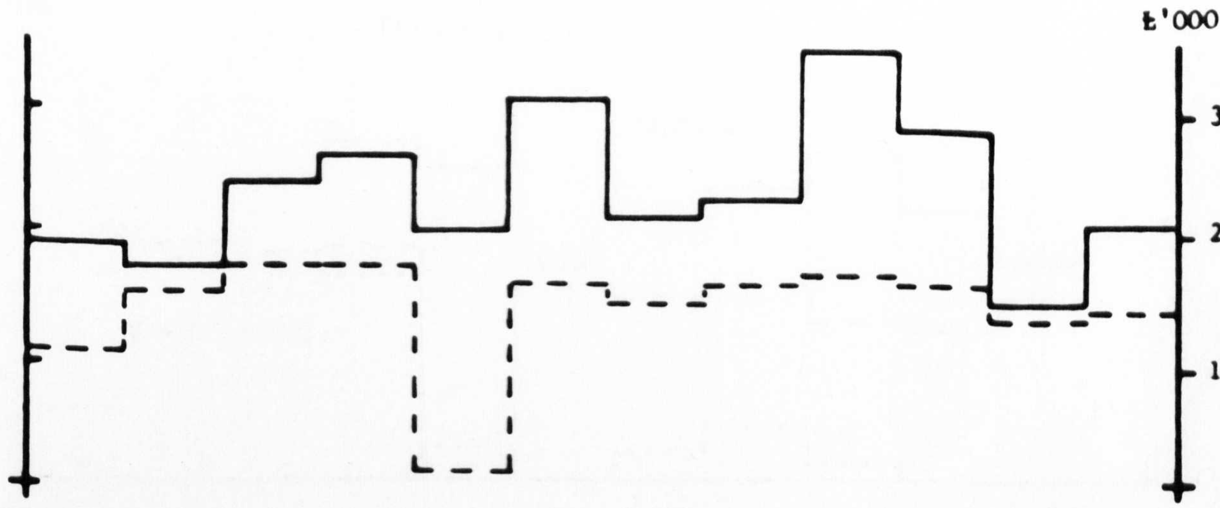
PLANNING PERIOD :FROM NOV '71 TO OCT '72

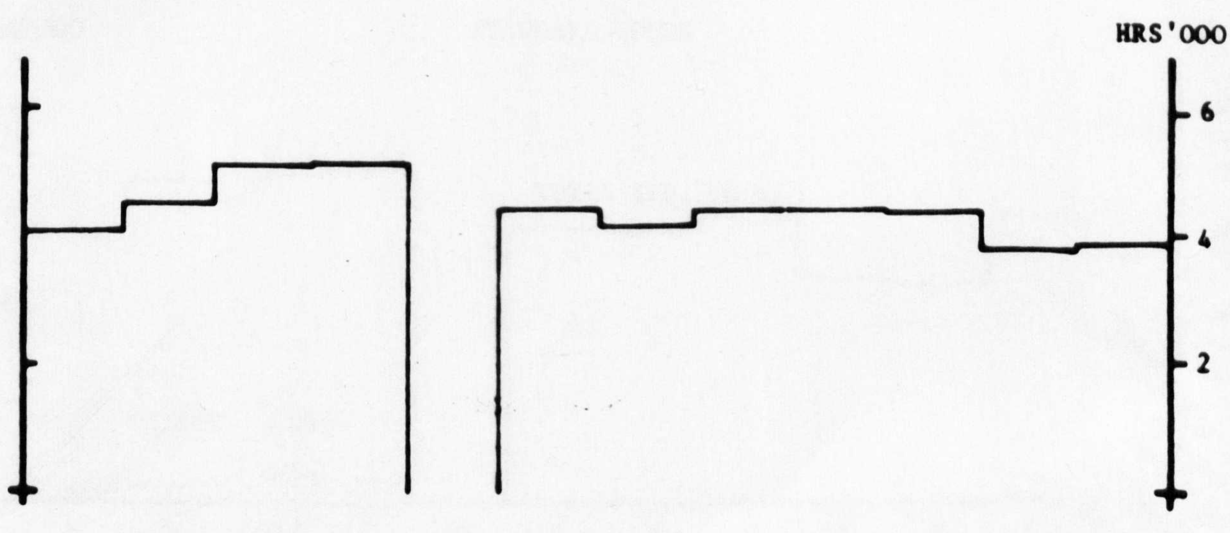
DATE OF . SALES FORECAST:24/05/71

. COMPUTER RUN :06/06/71

DAYS / MONTH	20 NOV	22 DEC	20 JAN	20 FEB	24 MAR	19 APR	20 MAY	20 JUN	15 JUL	15 AUG	24 SEP	20 OCT	239 TOTAL
II FINANCIAL SUMMARY													F'000
REVENUE	388	385	478	525	485	589	418	452	512	420	341	401	5394
COST	-212	-342	-344	-346	-21	-298	-283	-305	-239	-232	-289	-269	-3180
CONTRIBUTION	176	43	134	179	464	291	135	147	273	188	52	132	2214
F.M.I.	113	226	283	317	47	1	44	32	18		86	119	111
													F
OVTM PREMIUM	-4246	-5088	-4981	-5242		-2666	-1064	-2772	-2631	-2647		-9	-31396
SUBCON PREMIUM	-1815	-4195	-7116	-4979									-18106
F.M.I. HLDG	-1742	-4335	-4371	-4895	-894	-19	-672	-1533	-274		-1663	-1828	-22276
LOST SALES REV			20901	24959	38999								84858
III ACTIVITY SUMMARY													HRS'000
STANDARD HOURS	80	98	100	102		84	82	38	68	67	89	75	933
MADE IN	78	93	92	96		84	82	38	68	67	89	75	912
SUBCONTRACTED	2	5	8	6									21
MANPOWER (DIRECT)	174	188	204	215	211	219	218	214	213	210	207	207	207
OVERTIME - HOURS	6542	7840	7676	8079		4354	1773	4620	4468	4411		15	49778
- PERCENT	23.50	23.64	23.50	23.50	.	13.10	5.09	13.48	17.50	17.50	.	.05	13.40
IV SALES SUMMARY - %													%
FWDT	9.82	19.79	27.69	29.02	27.49	42.03	31.89	29.49	40.92	39.90	42.45	44.64	32.11
DRILL	9.31	15.10	9.98	8.31	.	1.35	.35	7.31	9.24	7.31	5.29	.	6.18
LOADER	9.08	8.41	10.03	9.21	9.29	9.39	8.72	9.37	7.92	7.22	8.17	8.69	8.84
DIGGER	71.92	56.75	52.17	53.60	63.41	47.38	59.09	52.30	41.98	45.80	44.22	46.79	52.99

ADJUSTED TO DAILY RATES





SUMMARY OF RESULTS OF STRIKE

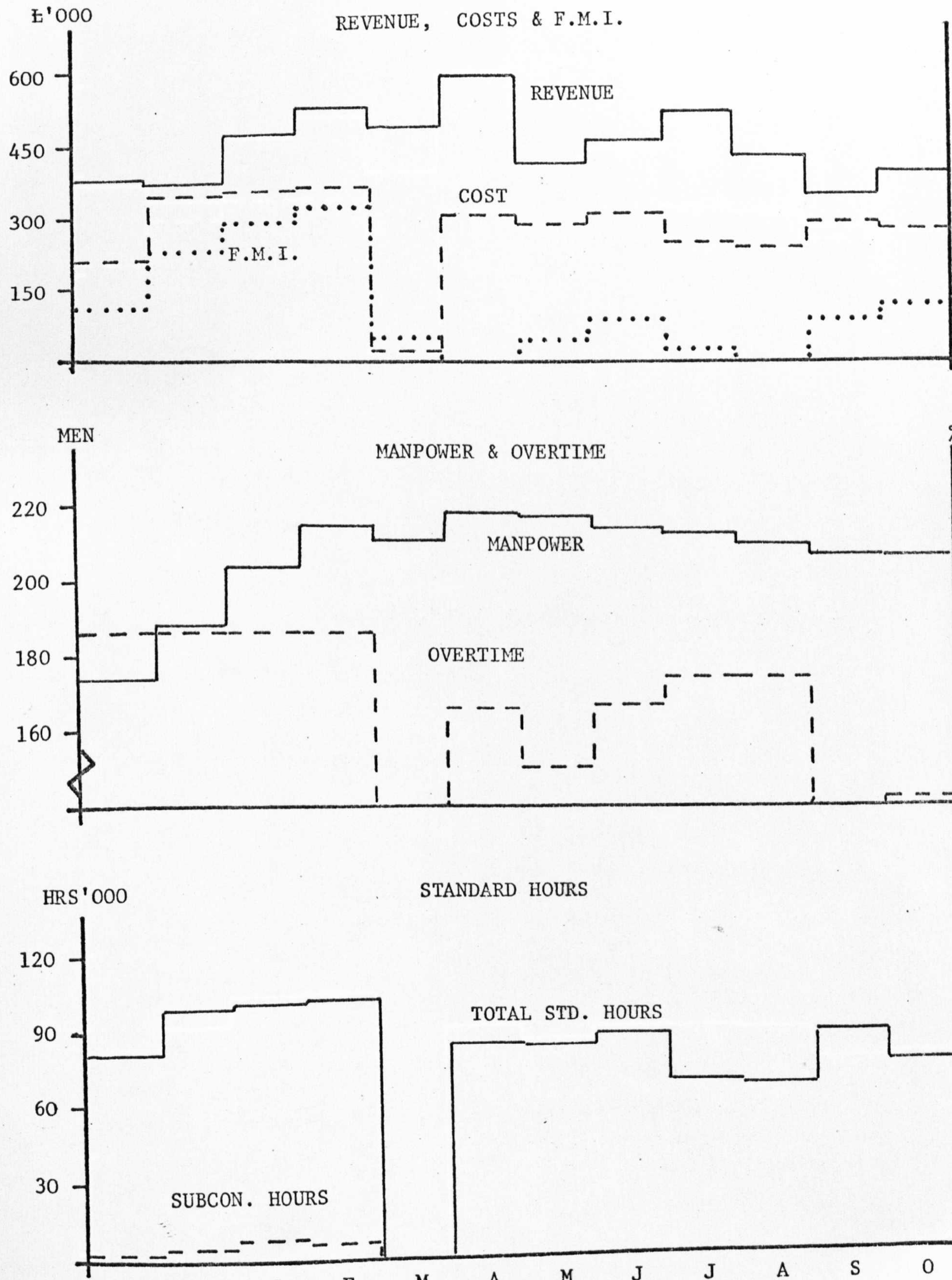


Exhibit 5.5

SUMMARY OF RESULTS OF STRIKE

ADJUSTED TO DAILY RATES

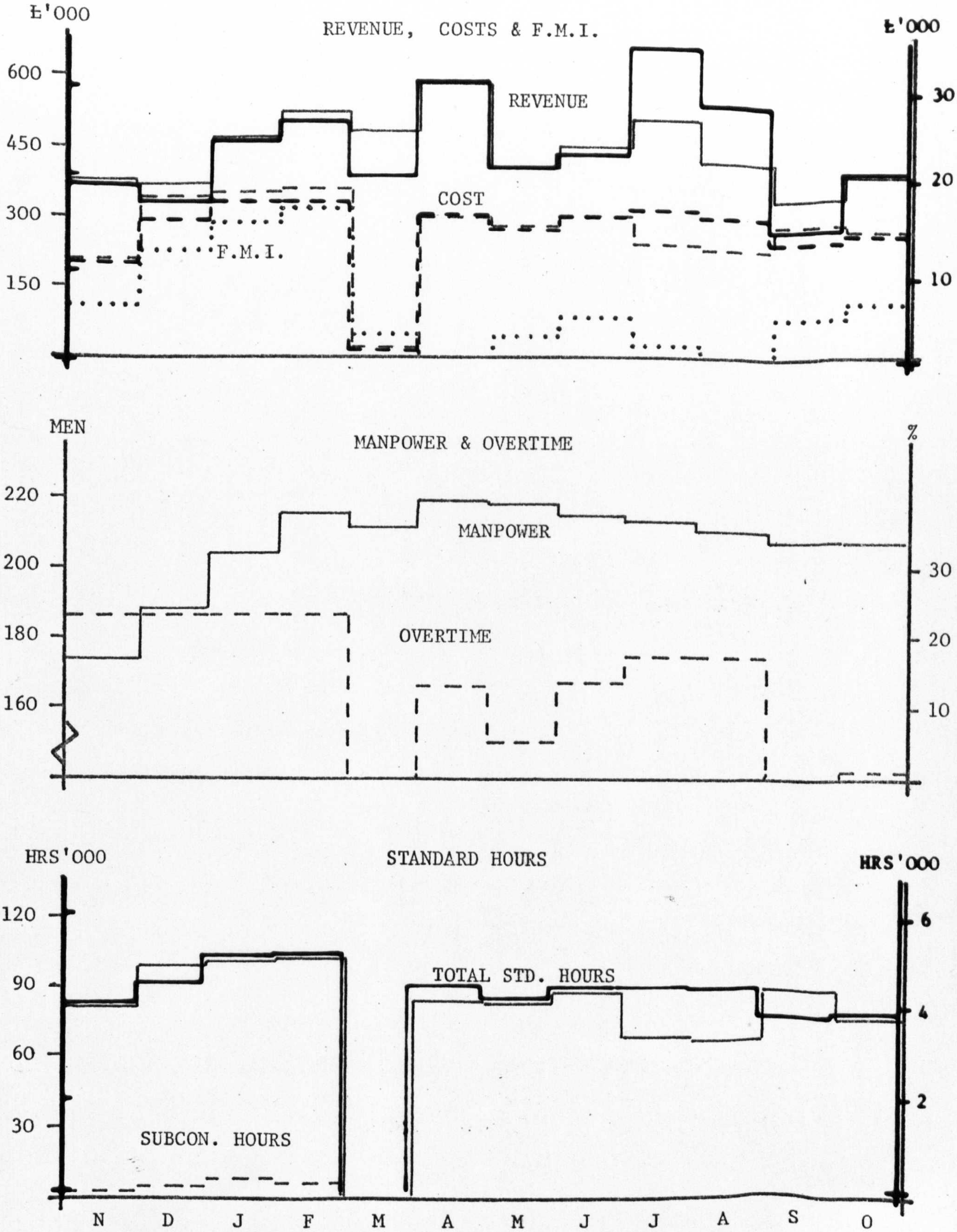


Exhibit 5.5

The lost sales are entirely of drills and are caused by the cumulative supply of hydraulic rams being insufficient for the cumulative demands of both drills and loaders. In fact some rams delivered in the first three months are stored and used to alleviate the shortage in February (it is cheaper to store rams than products) even though this means losing sales in January. The lost sales in March are due to the inventory of drills being exhausted back in January. For a more detailed explanation of the supply/demand situation for rams, see Exhibit 5.6.

Having hit a plateau in April and May, manpower falls away as fast as natural wastage will allow.

The high contribution (cash flow) in March is due to the high sales (the third highest) being met by almost liquidating inventories and there being no production costs to set against the cash inflow.

Of the big jump in standard hours between November and December, three are due to subcontracting work, another nine to the addition of two more working days and six to the extra fourteen men.

3.2. Full Optimal Solution

The full optimal solution report consists of a Rows Section and a Columns Section. The former contains information on: the row activity, slack activity, upper and lower limits and the dual activity. Information for the latter includes the column activity, input cost, upper and lower limits and the reduced cost. Examples of the printout are shown as Exhibits 5.11 to 5.17 on pages 5.36 to 5.42.

ERRATA

Page 5.17, Exhibit 5.6

The Lost Sales of the Drill should read -, -, 58, 69, -.
For Forecast Sales of the Drill instead of 101, read 161.

DELIVERY SHORTFALL OF RAMS

	Nov.	Dec.	Jan.	Feb.	Mar.	
DRILL	-	-	-	-	-	Lost sales
Open Inv.	100	101	190	190	108	Forecast sales
67	122	98	106	121	-	Production
	89	26	-	-	-	F.M.I.
LOADER	-	-	-	-	-	Lost sales
Open Inv.	86	79	117	118	110	Forecast sales
154	74	51	124^x	124^x	-	Production
	142	114	121	127	17^+	F.M.I.
RAMS	196	149	230	245	-	Usage
	200	220	200	200	240	Delivery
	4	75	45	-	240	Inventory

\+ F.M.I. in April is zero

x Production of the Loader is at the upper limit allowed by special purpose equipment, including use during overtime.

Note The reason the model chooses to forego sales of drills in January in order to produce loaders in February to sell in April (when the loader F.M.I. is nil) is that the marginal revenue of the latter policy exceeds that of the former, as can be seen from calculating the effects of making 1 less loader and 1 more drill in February.

Exhibit 5.6.

.../...

	DRILL	LOADER
	₺	₺
Sales Revenue	361.10	409.75
Costs - Production	184.65	188.97
Subcontract Premium	109.70	92.53
Holding Cost	-	7.20
	294.35	288.70
Marginal Revenue	66.75 increase	121.05 decrease

All departments are subcontracting work in February. Making 1 less loader does not alter the situation. The manufacture of 1 more drill will therefore involve subcontracting work.

The result of increased drill production by 1 unit in February would be to reduce revenue by ₺54.3.

Exhibit 5.6

The information in the report is of two kinds. On the one hand there are the activity values of all the structural and logical variables. From these it is possible to draw up production and manpower schedules for products and departments. Also the input costs make it easy to derive the corresponding financial summaries. The one-page summary shown earlier used these methods and presented aggregated data. The reports I developed for M-F gave the individual product/department information.

On the other hand, the full optimal solution report gives the marginal costs or shadow prices of the variables which are at limit level. Marginal costs are defined as the rate of change in the objective function per unit change in the activity of a variable. For a maximisation problem, the marginal costs of variables at lower limit indicate the amount by which the variable is 'overpriced' to be included in the optimal solution. For variables at upper limit, the marginal costs represent the increase in contribution from relaxing the bounds by 1 unit. Shadow prices (dual activities) are associated with the logical variables and indicate the rate of change in the objective function when requirements for products or the supply of resources change.

The marginal costs and shadow prices can be used to help identify the areas with the most profit improvement potential. One of the peices of information missing from the report is the range over which the marginal cost is valid, i.e. how many units can be introduced at the rate/unit given by the marginal cost.

Exhibit 5.7 overleaf shows one method of summarising the profit improvement information contained in the Rows and Columns Sections of the full optimal solution for February. The formulation of policy requires the tables to be extended over the whole planning period and the addition of the information from the post-optimal results. The latter is covered below in 3.3.

The figures can be interpreted in two ways. Firstly, as they are presented, i.e. the increase in profits from the sale of an extra F.W.D. (£1148.7), or from increasing the capacity of the special purpose equipment for the F.W.D. by one unit (£76.9), or from installing one unit more of general purpose equipment in the primary department (£104.4). Secondly, by changing the sign, the figures are also the reduction in contribution from activity levels being less than planned. Thus if some machine in the primary department breaks down, causing one man to have to stop working, contribution will fall by £104.4. On the basis of the figures for the first four months, management might decide to step-up preventive maintenance. Alternatively, depending on the attitude to risk, maintenance might be cut to a minimum to maximise productive capacity during the period before the strike with the intention of overhauling equipment while the strike is on.

3.3. Post-Optimal Results

The post-optimal report gives the following types of information:

- The penalties of deviating from the planned activity levels. To be more precise: the penalties are either the decrease in the objective function per unit change in the activity

PROFIT IMPROVEMENT/UNIT SUMMARY

	SALES	F.M.I.	J & F [(1)]	RAM
	Ł	Ł	Ł	Ł
F.W.D.	1148.7		76.9	
DRILL		-3.2		66.8 [(2)]
LOADER	54.2		6.3	
DIGGER	381.8		23.5	

	STD. HRS.	OVT. AT 1 1/2 [(4)]	OVT. AT 2	GEN. PURPOSE EQUIP.	RECRUIT-ING PROC's	NATURAL [(3)] WASTAGE
	Ł	Ł	Ł	Ł	Ł	Ł
PRIMARY	0.8	31.2	9.0	104.4		-40.0
SECONDARY	0.8	33.8	9.5		149.7	-159.7
ASSEMBLY	0.8	39.4	11.4	15.9		-115.0

Notes

(1) J & F - special purpose equipment for each product.

(2) Shown jointly but in fact extra supplies would be used to build more Drills.

(3) The figures are the cost penalties if men leave for another job before the strike.

(4) The units for both rates of overtime are standard hours per man.

Exhibit 5.7

value of each variable in the basis, or the decrease in the objective function from variables at limit level backing off from the limit, i.e. variables at lower limit increasing in activity and those at upper limit decreasing.

. The robustness of the optimal solution to changes in input costs and prices. In other words, the optimal solution is insensitive to certain movements in costs and prices and the report identifies the range over which the indifference operates. This is helpful when considering either the accuracy with which to try to estimate costs or the impact of the residual uncertainty about the estimates.

. For variables at limit level, the total profit improvement from relaxing the constraint, i.e. the number of units for which the marginal cost is valid.

. The range of variation in activity levels over which the basis remains unchanged.

Examples of the post-optimal reports are given in Exhibits 5.22 to 5.25. The details for February are extracted in Exhibits 5.26 to 5.29.

Each of the first three categories; deviation penalties, robustness and profit improvement is considered in turn.

3.3.1. Penalties of Deviation

The brief summary, Exhibit 5.8, gives details of the more important variables, the magnitude of the penalty (in brackets) per unit change, the direction of change which will incur the penalty and sometimes a comment.

VULNERABILITY TO PROFIT TARGET

SALES: F.W.D. (-£1,149) and Digger (-£381); a drop in sales in February would be lost sales.

PRODUCTION: F.W.D. (-£77) and Digger (-£24); a drop in February would be made-up in an earlier period.

F.M.I.: Severe penalties for all products, except the Drill, for both increases and decrease. The worst is for a drop in F.W.D. (-£1,066).

MANPOWER: Primary (-£104) and Secondary (-£150) should not be allowed to drop. The high costs of training in assembly work (£110) lessen the consequences of a drop in Assembly and make subcontracting marginal work more attractive than otherwise.

OVERTIME: At least maintain the current policy in Primary (-£40) and Secondary (-£43).

HIRING: At least maintain the current rates of increase in Primary (-£104) and Secondary (-£150). Do not hire more than necessary for Assembly (-£115).

SUBCONTRACT: Should be kept to a minimum as costs of increasing are high, in Primary (-£84.5) and Secondary (-£121); the penalty is less in Assembly (-£13).

Exhibit 5.8

As can be seen from Exhibits 5.22 to 5.25, the reports do give the range over which these penalties are valid. By modifying the problem to make a variable have the activity shown by UPPER or LOWER ACTIVITY, it is possible to explore the consequences of changing the original plans.

The analysis in Exhibit 5.8 suggests that manpower policy has a bigger influence on profits than might be expected. Also the training policy of the assembly foreman does imply a different manpower policy in that department from the others.

3.3.2. Robustness

Exhibit 5.9 summarises the results for February. The full extract is contained in Exhibit 5.28. The purpose of the analysis is to identify the amount of variation in input costs to which the planned activity levels are indifferent.

When a variable is at its own limit level or is restrained by an associated variable being at limit level, any change in the input cost tending to make it move outside the present limit will have no effect. In other words, the optimum solution is insensitive to cost moves in such a direction.

The figures in Exhibit 5.9 are the percent to which the price/cost could move, not the amount by which it could do so.

The overall picture is of stability. The smallest margin for error is associated with product costs, which only have to drift upwards by 3% for the plan to change. A margin of this size can soon be eroded when the specification of products is being changed continuously to improve quality, add new features, etc.

ROBUSTNESS TO REVENUE & COST CHANGES

SALES:	Company net return could fall for all products except the Drill: F.W.D. (70%), Loader (87%), Digger (68%).
PRODUCTION:	Product costs could rise for all products, except the Drill, to 103%.
F.M.I.:	The plan is insensitive to any reasonable change in holding costs.
MANPOWER:	Costs could increase in all departments: Primary (227%), Secondary (282%), Assembly (119%).
OVERTIME:	The plan is similarly insensitive to foreseeable changes in Overtime costs: Primary (339%), Secondary (357%), Assembly (196%). The percentages for Sunday overtime are higher still.
SUBCONTRACT:	The amount of work subcontracted would remain as planned for reductions in costs to Primary (69%), Secondary (58%), Assembly (96%).
HIRING:	The number of people recruited or leaving is insensitive to the relevant costs.

Exhibit 5.9

3.3.3. Profit Improvement

The main areas for profit improvement in February are detailed in Exhibit 5.10. The figures are taken from Exhibit 5.29 later in the appendix.

Some of the information may appear to be intuitively obvious. However, although it might be reasonable to expect, say, extra F.W.D.'s to make an important contribution to profits, at least four other peices of information are required:

- In which month should the extra sales come?
- How many extra units can be produced?
- In which month(s) should they be produced?
- How much is it worth paying to secure the extra sales?

The profit improvement analysis provides answers to the first two and the last. The model would need to be modified and rerun to answer the third.

Before action was taken on the basis of these figures, it would be necessary to see whether the same bottlenecks were recurring in other periods. If production of the F.W.D. was continually bumping up against the limit imposed by jigs and fixtures, it would be worthwhile exploring the possibilities of investment to increase their capacity.

However, if the potential savings are caused by the presence of the strike in the following month, then the figures can be used as a guide to what it would be worth paying to find short-term solutions to the bottlenecks, such as increasing efficiency, cutting down on maintenance time and so on.

TOTAL PROFIT IMPROVEMENT SUMMARY

	Profit/ Unit	Number of Units	TOTAL PROFIT	Comments
	Ł		Ł	
SALES: F.W.D.	1149	7	8041	
LOADER	54	14	756	
DIGGER	382	14	5345	
SUPPLIERS: RAM	67	67	4489	Used to make Drills
J & F: F.W.D.	77	22	1694	Production is limited by special purpose equipment.
LOADER	6	50	300	
CAPACITY: SECONDARY	0.8	5093	4074	Does not include cost of providing capacity. Units are std. hrs.
RECRUITING: SECONDARY	150	5	750	

Exhibit 5.10

4. ONE-PAGE SUMMARY

The report, Exhibit 5.4, is divided into four sections: headings, financial summary, activity summary and sales summary. It is supposed to be self-explanatory, nevertheless I will go through it quickly in case there are any ambiguities.

I The Headings

Management Policy. The purpose is to identify the situation(s) being analysed. This particular analysis explores some of the consequences of a factory shut-down in March.

Planning Period. Since the model is to be used as a rolling plan, it is necessary to identify the limits of the planning period. Although the model covers a 13 month period, the report is only concerned with the first 12, so that the results are comparable with those of the other systems. Information on the 13th month is available from the optimal solution report produced by MPS/360.

Sales Forecast. Sales forecasts are revised and approved by the M.D. every month. These forecasts are the most volatile data in the model. Changes in the forecast tend to affect the whole pattern of resource allocation. One of the disadvantages of the manual system of production scheduling was that it took over 1 month, after the sales forecast was approved, to produce the new plans for factory activity.

Computer Run. This is a useful guide to the time that has elapsed since the sales forecast and a means of keeping track of the status of the other data in the model: a necessary and difficult process with a large model.

Days and Months. Since the year is split into four and five week periods, some of the fluctuations are more apparent than real.

II The Financial Summary

Despite appearances, the figures are in pounds sterling; the type chain does not have the appropriate symbol. The figures in units of thousands are the integer part of the number (truncation instead of rounding). Consequently, there are sometimes small differences between the results on the summary and those in the full optimal solution printout. One or two comments I make about particular variables cannot be deduced from the one-page summary and in fact are taken from the full optimal solution printout, parts of which are illustrated in the next section, as Exhibits 5.11 to 5.17.

Revenue. These figures represent realisable sales not forecast sales. In other words, sales for which there is capacity and, in the absence of a policy to the contrary, which are profitable. The difference between forecast sales and realisable sales is shown in the line Lost Sales Revenue. There is no allowance for the giving of credit, although it would not be difficult to build this into either the model or the report-writing program. The figures are calculated by multiplying the activity value of each sales variable by its input cost (in MPS/360 language). This means that freight is shown as a reduction in sales revenue.

Cost. Again there are no adjustments here for credit from suppliers. The figures are calculated by multiplying activity values by input costs and summing by period. It is possible to introduce data at the report-writing stage, so one development would be to include management estimates of the remaining period costs. The costs are low in March because of the strike. In fact, most of the 21 should be taken out. The reason for this particular correction not being made is explained in Appendix 6 on using the model, which contains the example of a strike. The costs included here are 70% of all company expenses.

Contribution. The result of subtracting cost from revenue. The figures highlight the effects of seasonal sales, a month of lost productive capacity being used and increased at the maximum rate for the first three months and surplus production going into finished machines inventory to meet the sales in March and April. For instance, the low contribution in December is primarily due to efforts to double inventory between the first two months. Strictly speaking, contribution in this report corresponds more to cash flow than profits. In the accounting records the cost of finished products is first transferred to the inventory account and subsequently to the income statement as cost of goods sold. However, if the planned closing inventory is set equal to the opening inventory, the total contribution will be a good measure of profits.

F.M.I. Only finished machines inventory is included. As there are no limits on the size of finished machines inventory, for the present analysis, except for the first and last months (13th not 12th), the amounts represent that required to smooth production. The figure in the Total column, 111, is the straight average for the 12 months.

Premiums. Both overtime (OVTM) and subcontract (SUBCON) premiums are included in the Cost line above. They are split out here because, together with the inventory holding cost, they are good indicators of the mismatch between sales and productive capacity and of the erosion of profit margins. Together, the two account for £50,000, 16% of direct labour costs. The reason for these variables being the first to be affected by over or under-capacity is that manpower levels, one of the other two restrictions on capacity, are expensive to increase and difficult to decrease. Larger coefficients and smaller costs in the equations for restricting the rate of change in manpower reverse the order; the model then chooses constant rates of overtime and a more flexible approach to hiring and firing. The units are now pounds instead of thousands of pounds.

F.M.I. Hldg. The holding cost of finished machines inventory. Sometimes there appears to be an inconsistent relationship between the value of inventory and its holding cost. One explanation is that the latter is affected by the length of the period whereas the former is not. Another possibility is that the value of inventory and its holding cost are expressed in different units. It is possible for an inventory holding cost to be shown in a month where there is no F.M.I. The reason is that any value of F.M.I. below £1,000 will be truncated to zero.

Lost Sales Rev. The model is constructed to permit production to lead sales but not to lag them. If the sales target cannot be met, the model treats the shortfall as lost sales. Again, revenue is less the freight charge. The purpose of the figures is to signal the need to revise the sales forecast, or reverse some policy decision, as the present forecast is incompatible with the production programme.

III The Activity Summary

The report presents information on the physical data which generates the financial summary. Whereas the latter consists of activity values multiplied by input costs, the former is calculated from the activity values and the coefficients (matrix elements) of the decision variables.

Standard hours. Standard hours are the best unit for monitoring the overall factory workload. They are the one unit common to the measurement of the labour content of products and of the capacity of departments. There is no other homogeneous measure of throughput. Production control does its scheduling in these units and management thinks in them. The next two lines on the report show how the workload of the production programme is divided between the factory and subcontractors. When work is subcontracted, this takes the form of individual operations rather than whole products or major components. Work permanently routed through subcontractors is said to be sourced from an outside supplier (subcontracting is temporary), it does not appear in the figures for subcontracted standard hours or premium, and the cost is classified as direct material.

Manpower. The manpower in November 1971 is fixed, together with the upper limit on the level of manpower in each department (the constraint imposed by existing facilities). In fact, the maximum manpower with existing facilities is 220. During April, May and June two of the three departments are at maximum capacity. At the start of the year manpower is being increased at nearly the maximum rate. The 207 in the Total column is the average for the period.

Overtime. These are clock hours not standard hours. The percentage is calculated by comparison with the normal attendance hours. The maximum possible amount of overtime is about 23.5% per man, excluding Sunday afternoons which are reserved for short-term problems. The overtime percent illustrates the effect of linking the amount of overtime available to the number of men assigned to each month (the activity value of another variable). The figures under Total are the sum of the hours and the average of the percentages.

IV The Sales Summary.

The last section shows the breakdown each month of the sales revenue between the four products. Freight is included as a deduction from sales revenue. By making the model maximise contribution, the sales mix problem is solved at the same time as that of production scheduling. The figures in the last column are the averages for the 12 month period. Notice that in March all the drill sales are lost. Marketing had forecast 108. In October the forecast was zero as can be seen by reference to the Lost Sales Revenue line.

5. FULL OPTIMAL SOLUTION

This section retains the structure of the previous one: description is followed by explanation. The MPS/360 output of the optimal solution is divided into two parts: Section 1 concerns rows, Section 2 columns. Together, for this model, they occupy 15 pages. I have included three pages from Section 1 and four from Section 2. Full details of the system for assigning names to variables are given in Appendix 8 on constructing the model. Here I pick one or two as necessary. Both sections have similar structure and content and so will be described together, with differences being noted.

5.1. Row and Column Sections - Description

The two sections are illustrated as Exhibits 5.11 and 5.14. Each section is printed as a table of eight columns with one row of the table for each row or column of the problem. The columns in the table are taken from left to right.

NUMBER. This is the internal serial number of the row (strictly, the logical variable associated with the row) or column. If the work matrix contains m rows and n columns, the rows are numbered from 1 through m and the columns from m + 1 through m + n. These numbers are useful principally for analysis of the iteration log line where vectors are identified by their serial numbers. The iteration log is not shown.

NAME. (column heading: ROW or COLUMN). This is the eight-character name given to the row/column by the user.

FACTORY STRIKE IN MARCH   PAGE 30 - 72/257

SECTION 1 - ROWS

NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
1	SHTRTMTA	UL	.	.	NONE	.	.55035-
2	SWELDNGA	UL	.	.	NONE	.	.81534-
3	SASSMLYA	UL	.	.	NONE	.	.76444-
4	SHTRTTXA	UL	.	.	NONE	.	18.52754-
5	SWELDGXA	UL	.	.	NONE	.	43.27330-
6	SASSLYXA	UL	.	.	NONE	.	48.22192-
7	SHTRTTZA	UL	.	.	NONE	.	3.40706-
8	SWELDGZA	UL	.	.	NONE	.	9.52216-
9	SASSLYZA	UL	.	.	NONE	.	10.74659-
10	SHYDRAMA	BS	196.88727	3.11273	NONE	200.00000	.
11	SFWDTMSA	EQ	.	.	.	.	2566.69858
12	STRALMSA	EQ	.	.	.	.	353.90000
13	SLOADMSA	EQ	.	.	.	.	345.06242
14	SDIGGMSA	EQ	.	.	.	.	773.78847
15	SFWDTPSA	UL	10.00000	.	NONE	10.00000	1242.30142-
16	STRALPSA	UL	100.00000	.	NONE	100.00000	7.20000-
17	SLOADPSA	UL	86.00000	.	NONE	86.00000	64.68758-
18	SDIGGPSA	UL	235.00000	.	NONE	235.00000	413.61153-
19	SHTRTMTB	UL	.	.	NONE	.	.82802-
20	SWELDNGB	UL	.	.	NONE	.	.81499-
21	SASSMLYB	UL	.	.	NONE	.	.73231-
22	SHTRTTXB	UL	.	.	NONE	.	44.20989-
23	SWELDGXB	UL	.	.	NONE	.	47.16382-
24	SASSLYXB	UL	.	.	NONE	.	50.62507-
25	SHTRTTZB	UL	.	.	NONE	.	9.81648-
26	SWELDGZB	UL	.	.	NONE	.	10.34470-
27	SASSLYZB	UL	.	.	NONE	.	11.37242-
28	SHYDRAMB	BS	345.35968	74.64032	NONE	420.00000	.
29	SFWDTMSB	EQ	.	.	.	.	2577.56278
30	STRALMSB	EQ	.	.	.	.	357.10000
31	SLOADMSB	EQ	.	.	.	.	348.26242
32	SDIGGMSB	EQ	.	.	.	.	783.58847
33	SFWDTPSB	UL	20.00000	.	NONE	20.00000	1231.43722-
34	STRALPSB	UL	161.00000	.	NONE	161.00000	4.00000-
35	SLOADPSB	UL	79.00000	.	NONE	79.00000	61.48758-
36	SDIGGPSB	UL	184.00000	.	NONE	184.00000	403.81153-
37	SHTRTTCB	EQ	.	.	.	.	545.67234
38	SWELDGCB	EQ	.	.	.	.	741.93547
39	SASSLYCB	EQ	.	.	.	.	717.78233
40	SHTRTTUB	LL	.	.	.	NONE	510.67234
41	SWELDGUB	LL	.	.	.	NONE	706.93547
42	SASSLYUB	LL	.	.	.	NONE	607.78233
43	SHTRTTDB	BS	.23000	.23000-	.	NONE	.
44	SWELDGDB	BS	2.12000	2.12000-	.	NONE	.
45	SASSLYDB	BS	.45000	.45000-	.	NONE	.
46	SHTRTMTC	UL	.	.	NONE	.	.82779-
47	SWELDNGC	UL	.	.	NONE	.	.81534-
48	SASSMLYC	UL	.	.	NONE	.	.79167-
49	SHTRTTXC	UL	.	.	NONE	.	40.16798-

Exhibit 5.11

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FACTORY STRIKE IN MARCH PAGE 31 - 72/257

NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
50	SWELDGXC	UL	.	.	NONE	.	43.27330-
51	SASSLYXC	UL	.	.	NONE	.	50.80833-
52	SHTRTTZC	UL	.	.	NONE	.	8.95589-
53	SWELDGZC	UL	.	.	NONE	.	9.52216-
54	SASSLYZC	UL	.	.	NONE	.	11.40000-
55	SHYDRAMC	BS	575.11985	44.88015	NONE	620.00000	.
56	SFWDTMSC	EQ	.	.	.	.	2623.46278
57	STRALMSC	EQ	.	.	.	.	361.10000
58	SLOADMSC	EQ	.	.	.	.	352.26242
59	SDIGGMSC	EQ	.	.	.	.	795.78847
60	SFWDTPSC	UL	35.00000	.	NONE	35.00000	1185.53722-
61	STRALPSC	BS	132.11985	57.88015	NONE	190.00000	.
62	SLOADPSC	UL	117.00000	.	NONE	117.00000	57.48758-
63	SDIGGPSC	UL	210.00000	.	NONE	210.00000	391.61153-
64	SHTRTTCC	EQ	.	.	.	.	266.76798
65	SWELDGCC	EQ	.	.	.	.	443.01088
66	SASSLYCC	EQ	.	.	.	.	401.40833
67	SHTRTTUC	LL	.	.	.	NONE	231.76798
68	SWELDGUC	LL	.	.	.	NONE	408.01088
69	SASSLYUC	LL	.	.	.	NONE	291.40833
70	SHTRTTDC	BS	.25530	.25530-	.	NONE	.
71	SWELDGDC	BS	2.26840	2.26840-	.	NONE	.
72	SASSLYDC	BS	.49500	.49500-	.	NONE	.
73	SHTRTMTD	UL	.	.	NONE	.	.82779-
74	SWELDNGD	UL	.	.	NONE	.	.81534-
75	SASSMLYD	UL	.	.	NONE	.	.79167-
76	SHTRTTXD	UL	.	.	NONE	.	40.16798-
77	SWELDGXD	UL	.	.	NONE	.	43.27330-
78	SASSLYXD	UL	.	.	NONE	.	50.80833-
79	SHTRTTZD	UL	.	.	NONE	.	8.95589-
80	SWELDGZD	UL	.	.	NONE	.	9.52216-
81	SASSLYZD	UL	.	.	NONE	.	11.40000-
82	SHYDRAMD	UL	820.00000	.	NONE	820.00000	66.80674-
83	SFWDTMSD	EQ	.	.	.	.	2660.26278
84	STRALMSD	EQ	.	.	.	.	361.10000
85	SLOADMSD	EQ	.	.	.	.	355.46242
86	SDIGGMSD	EQ	.	.	.	.	805.58847
87	SFWDTPSD	UL	40.00000	.	NONE	40.00000	1148.73722-
88	STRALPSD	BS	120.88015	69.11985	NONE	190.00000	.
89	SLOADPSD	UL	118.00000	.	NONE	118.00000	54.28758-
90	SDIGGPSD	UL	237.00000	.	NONE	237.00000	381.81153-
91	SHTRTTCD	EQ	.	.	.	.	35.00000
92	SWELDGCD	EQ	.	.	.	.	184.66130
93	SASSLYCD	EQ	.	.	.	.	110.00000
94	SHTRTTUD	BS	1.45551	1.45551-	.	NONE	.
95	SWELDGUD	LL	.	.	.	NONE	149.66130
96	SASSLYUD	BS	4.89500	4.89500-	.	NONE	.
97	SHTRTTDD	BS	.28338	.28338-	.	NONE	.
98	SWELDGDD	BS	2.42719	2.42719-	.	NONE	.
99	SASSLYDD	BS	.54450	.54450-	.	NONE	.
100	SHTRTMTE	BS	11790.90000-	11790.90000	NONE	.	.

Exhibit 5.12

FACTORY STRIKE IN MARCH

NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
101	SWELDNGE	BS	53702.65101-	53702.65101	NONE	.	.
102	SASSMLYE	BS	26680.50000-	26680.50000	NONE	.	.
103	SHTRTTXE	BS	29.70000-	29.70000	NONE	.	.
104	SWELDGXE	BS	127.25747-	127.25747	NONE	.	.
105	SASSLYXE	BS	54.45000-	54.45000	NONE	.	.
106	SHTRTTZE	BS	.	.	NONE	.	.
107	SWELDGZE	BS	.	.	NONE	.	.
108	SASSLYZE	BS	.	.	NONE	.	.
109	SHYDRAME	BS	820.00000	240.00000	NONE	1060.00000	.
110	SFWDTMSE	EQ	.	.	.	.	2697.06278
111	STRALMSE	EQ	.	.	.	.	361.10000
112	SLOADMSE	EQ	.	.	.	.	358.66242
113	SDIGGMSE	EQ	.	.	.	.	815.38847
114	SFWDTPSE	UL	35.00000	.	NONE	35.00000	1111.93722-
115	STRALPSE	BS	.	108.00000	NONE	108.00000	.
116	SLOADPSE	UL	110.00000	.	NONE	110.00000	51.08758-
117	SDIGGPSE	UL	259.00000	.	NONE	259.00000	372.01153-
118	SHTRTTCE	EQ	.	.	.	.	93.26243-
119	SWELDGCE	EQ	.	.	.	.	64.40000-
120	SASSLYCE	EQ	.	.	.	.	167.12055-
121	SHTRTTUE	BS	3.30000	3.30000-	.	NONE	.
122	SWELDGUE	BS	9.08982	9.08982-	.	NONE	.
123	SASSLYUE	BS	5.50000	5.50000-	.	NONE	.
124	SHTRTTDE	LL	.	.	.	NONE	88.26243
125	SWELDGDE	LL	.	.	.	NONE	59.40000
126	SASSLYDE	LL	.	.	.	NONE	162.12055
127	SHTRTMTF	UL	.	.	NONE	.	.29455-
128	SWELDNGF	UL	.	.	NONE	.	.36000-
129	SASSMLYF	UL	.	.	NONE	.	.07419-
130	SHTRTTXF	BS	13.71008-	13.71008	NONE	.	.
131	SWELDGXF	UL	.	.	NONE	.	4.68000-
132	SASSLYXF	BS	53.90550-	53.90550	NONE	.	.
133	SHTRTTZF	BS	15.98992-	15.98992	NONE	.	.
134	SWELDGZF	BS	104.48962-	104.48962	NONE	.	.
135	SASSLYZF	UL	.	.	NONE	.	11.15536-
136	SHYDRAMF	BS	965.94914	284.05086	NONE	1250.00000	.
137	SFWDTMSF	EQ	.	.	.	.	2742.96278
138	STRALMSF	EQ	.	.	.	.	213.19147
139	SLOADMSF	EQ	.	.	.	.	362.66242
140	SDIGGMSF	EQ	.	.	.	.	662.84681
141	SFWDTPSF	UL	65.00000	.	NONE	65.00000	1066.03722-
142	STRALPSF	UL	22.00000	.	NONE	22.00000	147.90853-
143	SLOADPSF	UL	135.00000	.	NONE	135.00000	47.08758-
144	SDIGGPSF	UL	235.00000	.	NONE	235.00000	524.55319-
145	SHTRTTCF	EQ	.	.	.	.	6.13757
146	SWELDGCF	EQ	.	.	.	.	35.00000
147	SASSLYCF	EQ	.	.	.	.	68.35409-
148	SHTRTTUF	BS	3.26700	3.26700-	.	NONE	.
149	SWELDGUF	BS	1.16549	1.16549-	.	NONE	.
150	SASSLYUF	BS	5.44500	5.44500-	.	NONE	.
151	SHTRTTDF	BS	.29700	.29700-	.	NONE	.

Exhibit 5.13

ÉCOLE DES MINES DE PARIS

SECTION 2 - COLUMNS

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
344	PFWDTRIZ	EQ	5.00000	.	5.00000	5.00000	2566.69858
345	PTRALRIZ	EQ	67.00000	.	67.00000	67.00000	353.90000
346	PLOADRIZ	EQ	154.00000	.	154.00000	154.00000	345.06242
347	PDIGGRIZ	EQ	100.00000	.	100.00000	100.00000	773.78847
348	PFWDTRPA	BS	5.00000	2340.12000-	.	50.00000	.
349	PTRALRPA	BS	122.31268	184.65000-	.	188.00000	.
350	PLOADRPA	BS	74.57458	188.97000-	.	124.00000	.
351	PDIGGRPA	BS	237.00000	598.39000-	.	251.00000	.
352	MFWDTRPA	BS	10.00000	3809.00000	.	NONE	.
353	MTRALRPA	BS	100.00000	361.10000	.	NONE	.
354	MLOADRPA	BS	86.00000	409.75000	.	NONE	.
355	MDIGGRPA	BS	235.00000	1187.40000	.	NONE	.
356	PFWDTRIA	LL	.	36.80000-	.	NONE	25.93580-
357	PTRALRIA	BS	89.31268	3.20000-	.	NONE	.
358	PLOADRIA	BS	142.57458	3.20000-	.	NONE	.
359	PDIGGRIA	BS	102.00000	9.80000-	.	NONE	.
360	DHTRTTNA	EQ	23.00000	82.40000-	23.00000	23.00000	720.14071
361	DHTRTTXA	BS	23.00000	16.80000-	.	NONE	.
362	DHTRTTZA	BS	23.00000	7.60000-	.	NONE	.
363	DHTRTTSA	LL	.	274.00000-	.	NONE	91.83313-
364	DWELDGNA	EQ	106.00000	82.40000-	106.00000	106.00000	1039.29425
365	DWELDGXA	BS	106.00000	16.80000-	.	NONE	.
366	DWELDGZA	BS	106.00000	7.60000-	.	NONE	.
367	DWELDGSA	BS	6.32479	287.00000-	.	NONE	.
368	DASSLYNA	EQ	45.00000	82.40000-	45.00000	45.00000	1056.27450
369	DASSLYXA	BS	45.00000	16.80000-	.	NONE	.
370	DASSLYZA	BS	45.00000	7.60000-	.	NONE	.
371	DASSLYSA	LL	.	323.00000-	.	NONE	11.10798-
372	PFWDTRPB	BS	48.00000	2340.12000-	.	55.00000	.
373	PTRALRPB	BS	98.04700	184.65000-	.	210.00000	.
374	PLOADRPB	BS	50.42542	188.97000-	.	136.00000	.
375	PDIGGRPB	UL	286.00000	598.39000-	.	286.00000	4.80707
376	MFWDTRPB	BS	20.00000	3809.00000	.	NONE	.
377	MTRALRPB	BS	161.00000	361.10000	.	NONE	.
378	MLOADRPB	BS	79.00000	409.75000	.	NONE	.
379	MDIGGRPB	BS	184.00000	1187.40000	.	NONE	.
380	PFWDTRIB	BS	28.00000	45.90000-	.	NONE	.
381	PTRALRIB	BS	26.35968	4.00000-	.	NONE	.
382	PLOADRIB	BS	114.00000	4.00000-	.	NONE	.
383	PDIGGRIB	BS	204.00000	12.20000-	.	NONE	.
384	DHTRTTNB	BS	25.53000	92.20000-	.	30.00000	.
385	DHTRTTXB	BS	25.53000	18.60000-	.	NONE	.
386	DHTRTTZB	BS	25.53000	8.40000-	.	NONE	.
387	DHTRTTSB	BS	1.36603	301.40000-	.	NONE	.
388	DWELDGNB	BS	113.42000	92.20000-	.	135.00000	.
389	DWELDGXB	BS	113.42000	18.60000-	.	NONE	.
390	DWELDGZB	BS	113.42000	8.40000-	.	NONE	.
391	DWELDGSB	BS	11.99621	315.40000-	.	NONE	.
392	DASSLYNB	BS	49.50000	92.20000-	.	55.00000	.

Exhibit 5.14

FACTORY STRIKE IN MARCH PAGE 38 - 72/257

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
393	DASSLYXB	BS	49.50000	18.60000-	.	NONE	.
394	DASSLYZB	BS	49.50000	8.40000-	.	NONE	.
395	DASSLYSB	LL	.	355.40000-	.	NONE	26.59191-
396	DHTRTTUB	BS	2.53000	35.00000-	.	NONE	.
397	DWELDGUB	BS	7.42000	35.00000-	.	NONE	.
398	DASSLYUB	BS	4.50000	110.00000-	.	NONE	.
399	DHTRTTDB	LL	.	5.00000-	.	NONE	550.67234-
400	DWELDGDB	LL	.	5.00000-	.	NONE	746.93547-
401	DASSLYDB	LL	.	5.00000-	.	NONE	722.78233-
402	PFWDTRPC	UL	50.00000	2340.12000-	.	50.00000	40.09235
403	PTRALRPC	BS	105.76016	184.65000-	.	188.00000	.
404	PLOADRPC	UL	124.00000	188.97000-	.	124.00000	3.08745
405	PDIGGRPC	UL	251.00000	598.39000-	.	251.00000	13.74921
406	MFWDTRPC	BS	35.00000	3809.00000	.	NONE	.
407	MTRALRPC	BS	132.11985	361.10000	.	NONE	.
408	MLOADRPC	BS	117.00000	409.75000	.	NONE	.
409	MDIGGRPC	BS	210.00000	1187.40000	.	NONE	.
410	PFWDTRIC	BS	43.00000	36.80000-	.	NONE	.
411	PTRALRIC	LL	.	3.20000-	.	NONE	3.20000-
412	PLOADRIC	BS	121.00000	3.20000-	.	NONE	.
413	PDIGGRIC	BS	245.00000	9.80000-	.	NONE	.
414	DHTRTTNC	BS	28.33830	82.40000-	.	30.00000	.
415	DHTRTTXC	BS	28.33830	16.80000-	.	NONE	.
416	DHTRTTZC	BS	28.33830	7.60000-	.	NONE	.
417	DHTRTTSC	BS	2.33753	274.00000-	.	NONE	.
418	DWELDGNC	BS	121.35940	82.40000-	.	135.00000	.
419	DWELDGXC	BS	121.35940	16.80000-	.	NONE	.
420	DWELDGZC	BS	121.35940	7.60000-	.	NONE	.
421	DWELDGSC	BS	22.56254	287.00000-	.	NONE	.
422	DASSLYNC	BS	54.45000	82.40000-	.	55.00000	.
423	DASSLYXC	BS	54.45000	16.80000-	.	NONE	.
424	DASSLYZC	BS	54.45000	7.60000-	.	NONE	.
A 425	DASSLYSC	LL	.	323.00000-	.	NONE	.
426	DHTRTTUC	BS	2.80830	35.00000-	.	NONE	.
427	DWELDGUC	BS	7.93940	35.00000-	.	NONE	.
428	DASSLYUC	BS	4.95000	110.00000-	.	NONE	.
429	DHTRTTDC	LL	.	5.00000-	.	NONE	271.76798-
430	DWELDGDC	LL	.	5.00000-	.	NONE	448.01038-
431	DASSLYDC	LL	.	5.00000-	.	NONE	406.40833-
432	PFWDTRPD	UL	50.00000	2340.12000-	.	50.00000	76.89235
433	PTRALRPD	BS	120.88015	184.65000-	.	188.00000	.
434	PLOADRPD	UL	124.00000	188.97000-	.	124.00000	6.28745
435	PDIGGRPD	UL	251.00000	598.39000-	.	251.00000	23.54921
436	MFWDTRPD	BS	40.00000	3809.00000	.	NONE	.
437	MTRALRPD	BS	120.88015	361.10000	.	NONE	.
438	MLOADRPD	BS	118.00000	409.75000	.	NONE	.
439	MDIGGRPD	BS	237.00000	1187.40000	.	NONE	.
440	PFWDTRID	BS	53.00000	36.80000-	.	NONE	.
441	PTRALRID	LL	.	3.20000-	.	NONE	3.20000-
442	PLOADRID	BS	127.00000	3.20000-	.	NONE	.
443	PDIGGRID	BS	259.00000	9.80000-	.	NONE	.

Exhibit 5.15

ÉCOLE DES MINES DE PARIS

FACTORY STRIKE IN MARCH

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
444	DHTRTTND	UL	30.00000	82.40000-	.	30.00000	104.38817
445	DHTRTTXD	BS	30.00000	16.80000-	.	NONE	.
446	DHTRTTZD	BS	30.00000	7.60000-	.	NONE	.
447	DHTRTTSD	BS	1.16861	274.00000-	.	NONE	.
448	DWELDGND	BS	129.85456	82.40000-	.	135.00000	.
449	DWELDGXD	BS	129.85456	16.80000-	.	NONE	.
450	DWELDGZD	BS	129.85456	7.60000-	.	NONE	.
451	DWELDGSD	BS	14.19481	287.00000-	.	NONE	.
452	DASSLYND	UL	55.00000	82.40000-	.	55.00000	15.90899
453	DASSLYXD	BS	55.00000	16.80000-	.	NONE	.
454	DASSLYZD	BS	55.00000	7.60000-	.	NONE	.
455	DASSLYSD	BS	1.81118	323.00000-	.	NONE	.
456	DHTRTTUD	BS	1.66170	35.00000-	.	NONE	.
457	DWELDGUD	BS	8.49516	35.00000-	.	NONE	.
458	DASSLYUD	BS	.55000	110.00000-	.	NONE	.
459	DHTRTTDD	LL	.	5.00000-	.	NONE	40.00000-
460	DWELDGDD	LL	.	5.00000-	.	NONE	189.66130-
461	DASSLYDD	LL	.	5.00000-	.	NONE	115.00000-
462	PFWDTRPE	EQ	.	2340.12000-	.	.	356.94278
463	PTRALRPE	EQ	.	184.65000-	.	.	176.45000
464	PLOADRPE	EQ	.	188.97000-	.	.	169.69242
465	PDIGGRPE	EQ	.	598.39000-	.	.	216.99847
466	MFWDTRPE	BS	35.00000	3809.00000	.	NONE	.
467	MTRALRPE	BS	.	361.10000	.	NONE	.
468	MLOADRPE	BS	110.00000	409.75000	.	NONE	.
469	MDIGGRPE	BS	259.00000	1187.40000	.	NONE	.
470	PFWDTRIE	BS	18.00000	45.90000-	.	NONE	.
471	PTRALRIE	LL	.	4.00000-	.	NONE	151.90853-
472	PLOADRIE	BS	17.00000	4.00000-	.	NONE	.
473	PDIGGRIE	LL	.	12.20000-	.	NONE	164.74166-
474	DHTRTTNE	BS	29.70000	99.40000-	.	30.00000	.
475	DHTRTTXE	LL	.	20.40000-	.	NONE	20.40000-
476	DHTRTTZE	LL	.	9.20000-	.	NONE	9.20000-
477	DHTRTTSE	LL	.	328.80000-	.	NONE	328.80000-
478	DWELDGNE	BS	127.25747	99.40000-	.	135.00000	.
479	DWELDGXE	LL	.	20.40000-	.	NONE	20.40000-
480	DWELDGZE	LL	.	9.20000-	.	NONE	9.20000-
481	DWELDGSE	LL	.	343.80000-	.	NONE	343.80000-
482	DASSLYNE	BS	54.45000	99.40000-	.	55.00000	.
483	DASSLYXE	LL	.	20.40000-	.	NONE	20.40000-
484	DASSLYZE	LL	.	9.20000-	.	NONE	9.20000-
485	DASSLYSE	LL	.	387.80000-	.	NONE	387.80000-
486	DHTRTTUE	LL	.	35.00000-	.	NONE	128.26243-
487	DWELDGUE	LL	.	35.00000-	.	NONE	99.40000-
488	DASSLYUE	LL	.	110.00000-	.	NONE	277.12055-
489	DHTRTTDE	BS	.30000	5.00000-	.	NONE	.
490	DWELDGDE	BS	2.59709	5.00000-	.	NONE	.
491	DASSLYDE	BS	.55000	5.00000-	.	NONE	.
492	PFWDTRPF	UL	47.00000	2340.12000-	.	47.00000	325.77288
493	PTRALRPF	BS	27.94914	184.65000-	.	180.00000	.
494	PLOADRPF	UL	118.00000	188.97000-	.	118.00000	137.50758

Exhibit 5.16

ÉCOLE DES MINES DE PARIS

FACTORY STRIKE IN MARCH PAGE 40 - 72/257

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
495	PDIGGRPF	BS	235.00000	598.39000-	.	249.00000	.
496	MFWDTRPF	BS	65.00000	3809.00000	.	NONE	.
497	MTRALRPF	BS	22.00000	361.10000	.	NONE	.
498	MLOADRPF	BS	135.00000	409.75000	.	NONE	.
499	MDIGGRPF	BS	235.00000	1187.40000	.	NONE	.
500	PFWDTRIF	LL	.	36.80000-	.	NONE	365.26547-
501	PTRALRIF	BS	5.94914	3.20000-	.	NONE	.
502	PLOADRIF	LL	.	3.20000-	.	NONE	146.76352-
503	PDIGGRIF	LL	.	9.80000-	.	NONE	16.87791-
504	DHTRTTNF	BS	29.70000	78.80000-	.	30.00000	.
505	DHTRTTXF	BS	15.98992	16.20000-	.	NONE	.
506	DHTRTTZF	LL	.	7.20000-	.	NONE	1.60354-
507	DHTRTTSF	LL	.	260.80000-	.	NONE	168.01818-
508	DWELDGNF	UL	135.00000	78.80000-	.	135.00000	9.86958
509	DWELDGXF	BS	135.00000	16.20000-	.	NONE	.
510	DWELDGZF	BS	30.51038	7.20000-	.	NONE	.
511	DWELDGSF	LL	.	272.80000-	.	NONE	152.56000-
512	DASSLYNF	BS	53.90550	78.80000-	.	55.00000	.
513	DASSLYXF	BS	.	16.20000-	.	NONE	.
514	DASSLYZF	LL	.	7.20000-	.	NONE	16.64908-
515	DASSLYSF	LL	.	306.80000-	.	NONE	278.01585-
516	DHTRTTUF	LL	.	35.00000-	.	NONE	28.86243-
517	DWELDGUF	BS	7.74253	35.00000-	.	NONE	.
518	DASSLYUF	LL	.	110.00000-	.	NONE	178.35409-
519	DHTRTTDF	LL	.	5.00000-	.	NONE	11.13757-
520	DWELDGDF	LL	.	5.00000-	.	NONE	40.00000-
521	DASSLYDF	BS	.54450	5.00000-	.	NONE	.
522	PFWDTRPG	BS	45.00000	2340.12000-	.	50.00000	.
523	PTRALRPG	BS	65.72740	184.65000-	.	188.00000	.
524	PLOADRPG	BS	116.36149	188.97000-	.	124.00000	.
525	PDIGGRPG	BS	208.00000	598.39000-	.	251.00000	.
526	MFWDTRPG	BS	35.00000	3809.00000	.	NONE	.
527	MTRALRPG	BS	4.00000	361.10000	.	NONE	.
528	MLOADRPG	BS	89.00000	409.75000	.	NONE	.
529	MDIGGRPG	BS	208.00000	1187.40000	.	NONE	.
530	PFWDTRIG	BS	10.00000	36.80000-	.	NONE	.
531	PTRALRIG	BS	67.67655	3.20000-	.	NONE	.
532	PLOADRIG	BS	27.36149	3.20000-	.	NONE	.
533	PDIGGRIG	LL	.	9.80000-	.	NONE	7.22266-
534	DHTRTTNG	BS	29.40300	82.40000-	.	30.00000	.
535	DHTRTTXG	BS	7.78136	16.80000-	.	NONE	.
536	DHTRTTZG	LL	.	7.60000-	.	NONE	1.80690-
537	DHTRTTSG	LL	.	274.00000-	.	NONE	178.12414-
538	DWELDGNG	BS	135.00000	82.40000-	.	135.00000	.
539	DWELDGXG	BS	55.53697	16.80000-	.	NONE	.
540	DWELDGZG	LL	.	7.60000-	.	NONE	1.90968-
541	DWELDGSG	LL	.	287.00000-	.	NONE	191.61935-
542	DASSLYNG	BS	53.36645	82.40000-	.	55.00000	.
543	DASSLYXG	BS	.	16.80000-	.	NONE	.
544	DASSLYZG	LL	.	7.60000-	.	NONE	6.44696-
545	DASSLYSG	LL	.	323.00000-	.	NONE	245.89640-

Exhibit 5.17

STATUS (column heading: AT). This is a two-character code denoting the status that the row or column activity (4th column) has in the solution. Codes and their meanings are as follows:

BS - in the basis and feasible

** - in the basis and infeasible

FR - nonbasis free

EQ - nonbasis artificial or fixed

UL - nonbasis, activity at upper limit

LL - nonbasis, activity at lower limit

ACTIVITY. This is the value that the row or column activity takes in the solution. For columns, it is simply the solution value. For rows, however, what is printed is not the solution value of the corresponding logical variable. If the constraint is written as:

$$\sum_j a_{ij}x_j + l_i = b_i$$

where b_i is the R.H.S. and l_i is the logical variable, the quantity printed corresponds to:

$$\sum_j a_{ij}x_j$$

The user should be aware, however, that this quantity is computed from $b_i - l_i$ and not from the summation.

SLACK ACTIVITY (row section) and INPUT COST (column section). These are self-explanatory.

LOWER LIMIT. The algebraically lowest value that the activity (column 4) can take and remain feasible.

UPPER LIMIT. The algebraically highest value that the activity (column 4) can take and remain feasible.

DUAL ACTIVITY (row section) and REDUCED COST (column section). The dual activity is otherwise known as the simplex multiplier, and the vector of dual activities as the π vector. The reduced costs are otherwise knows as dj's. Note that the dual activity of a row is the reduced cost of the corresponding logical variable. The dj of a variable is the rate of increase in the objective function value per unit increase of the variable. When optimal, therefore the dj's of nonbasis variables at lower level are positive for a minimisation problem, but negative for a maximisation problem.

5.2. Explanation

The reduced costs and dual variables only give the rate of change of the objective function per unit change in the corresponding variable. From the full optimal solution report, illustrated in Exhibits 5.11 to 5.17, there is no indication of the range over which the rate of change is valid. For the latter information, the post-optimal (range) report is needed; see section 6 of the present appendix. My remarks about the reduced costs will ignore the fact that the number of units which can be introduced or removed from the solution at a particular cost/unit is unknown for the present. The rows section of the report is considered first. The main exhibit for the rows section is 5.12, with occasional references to the others.

5.2.1. Rows Section

Instead of discussing every row in one time period; one row, typical of each type of equation and restriction, is selected. The rows are identified by name and dual activity. February, month D, has been chosen because it is immediately prior to the strike.

73 SHTRTMTD - 0.82779 The restriction (equality after the addition of the slack variable) expresses the relationship between production in February and the capacity of the primary department. Because the row is at its upper limit (UL, column three), the value of the corresponding slack variable is zero (the entry in the column headed 'Slack Activity'). The Slack Activity is only non-zero when there is short-time working in the primary department during February. The negative sign against the dual variable means that if the value of the slack variable is increased from zero to 1, the value of the objective function will be reduced by £0.82779. Changing the value of the slack variable is equivalent to making compensating changes to the capacity of the primary department; the slack variable can be thought of as absorbing or releasing capacity. So another interpretation of the dual activity, in the present case, is the value of marginal increases or decreases in capacity in the primary department. From the Columns Section, Exhibit 5.16, it can be seen that the limit of existing facilities has been reached, Column 444, DHTRTTND. As far as the L.P. is aware, extra capacity can only come from subcontracting. The cost of subcontracting 1 standard hour is £0.82779. The magnitude and sign of the dual activity indicate that if in-house capacity could be increased,

it would be possible to save the cost of subcontracting the equivalent amount of work. Of course, the total saving is not Ŀ0.82779 per unit. From this must be subtracted the cost of providing the extra in-house capacity. There are a number of possibilities: increasing the proportion of men on nights, working overtime on Sunday afternoon, increasing the efficiency of the department through a revised bonus scheme, and so on. Rows 74 and 75 represent similar restrictions for the secondary and assembly departments respectively.

76 SHTRTTXD - 40.16798 The restriction limits the number of men who can work overtime, at 1 1/2, to the number on the regular payroll. Again, the slack has a value of zero and is interpreted in a similar manner to Row 73 above. If the value of the slack variable SHTRTTXD is increased from zero to 1 (now the units are men, whereas in 73 they were standard hours), the value of the objective function will fall by Ŀ40.16798. Increasing the value of the slack variable can only be accommodated by reducing the number of men working overtime at 1 1/2, Column 445, DHTRTTXD, Exhibit 5.16. Reducing DHTRTTXD requires a similar reduction in the number of men working Sunday overtime, Column 446, DHTRTTZD, and equation (h) Appendix 4. There are three ways of compensating for this double drop in overtime capacity: either cut back production or build in an earlier period and store or make up the deficiency by extra subcontracting. The latter turns out to be the cheapest. The cost of subcontracting minus the saving in direct labour costs is Ŀ40.16798. Exhibit 5.18 overleaf shows the calculation. In the context of the comments above, the significance of the dual activity is that the marginal value of more

overtime at 1 1/2, with a corresponding increase in Sunday overtime, would save Ŀ40.16798 per 78 standard hours. The marginal value of more overtime at 1 1/2, without a corresponding increase in Sunday overtime (the ratio is 2.9 : 1), can be calculated; it is Ŀ31.6.

DUAL ACTIVITY FOR SHTRTTXD

76 SHTRTTXD - 40.16798

ROWS	COLUMNS			
	DHTRTTND	DHTRTTXD	DHTRTTZD	DHTRTTSD
SHTRTTND	-331.0	-58.0	-20.0	-331.0
SHTRTTXD	-1	1		
SHTRTTZD		-1	1	
ENTRPREN	-82.4	-16.8	-7.6	-274.0
ACTIVITY	30.0	30.0	30.0	1.17

THE RESTRICTIONS ARE OF THE FORM:

OVERTIME MANPOWER $\leq$ NORMAL MANPOWER or OVT. MEN - NORM. MEN + SLACK = 0

If the activity value of the slack variable SHTRTTXD is increase by 1 unit, either the value of DHTRTTND will have to be increased or that of DHTRTTXD decreased. DHTRTTND is already at its upper limit. In the case of decreasing DHTRTTXD, the value of DHTRTTZD must also be decreased according to the restriction of row SHTRTTZD. The effect of reducing the activity values of both DHTRTTXD and DHTRTTZD by 1 is to reduce capacity in the primary department by 78.0 standard hours. The choice is between reducing production or increasing capacity elsewhere. Utilising existing capacity is usually cheaper than losing sales. DHTRTTZD must fall by 1 unit in line with DHTRTTXD. Only DHTRTTSD remains. The cost of an extra 78.0 standard hours subcontracting is Ŀ64.5680. The saving in overtime costs (for DHTRTTXD and DHTRTTZD) is Ŀ16.8 + Ŀ7.6 = Ŀ24.4. The overall cost penalty of reducing overtime and a compensating increase in subcontracting is - Ŀ64.568 + Ŀ24.4 = - Ŀ40.168.

Exhibit 5.18

It should be remembered that although restriction 76 is expressed in men, because DHTRTTXD also appears in restriction 73, it operates in terms of standard hours. Thus management might wish to review the policy of the dayshift only working 5 hours of overtime on Saturday and 4 on Sunday. Rows 77 and 78 bear the same relationship to the other two departments that Row 76 has to the primary.

79 SHTRTTZD - 8.95589 The restriction limits the number of men available for Sunday overtime to those available for overtime at 1 1/2. The interpretation is analogous to 76 above without the complication of a parallel change in the capacity available at another rate of overtime. The dual activity represents the value of not sub-contracting 20 standard hours, and increasing the amount of Sunday overtime correspondingly. The saving on the former is Ł16.556 (20.0 / 331.0 X Ł274.0), the cost of the latter is Ł7.6, a net saving of Ł8.956. There are in fact 20 standard hours per man potentially available on Sunday afternoons.

Rows 80 and 81 are similar to 79.

82 SHYDRAMD - 66.80674 The restriction limits the cumulative production of drills and loaders to the cumulative delivery of hydraulic rams. The reduced cost of the slack variable means that if the value of the slack was increased from zero to 1, the value of the objective function would be reduced by Ł66.81, because one less drill would be produced and sold. (If the L.P. has to choose between making and selling drills and making and selling loaders, the latter has preference.) As a dual activity the interpretation is that if 1 more ram were made available,

821 in place of 820, one more drill would be produced and sold, consequently the objective function would increase by Ł66.80679. For instance, management might want to consider airfreighting rams from Europe for the months in which they were in short supply.

83 SFWDTMSD 2660.26278 The row and artificial variable are associated with the balance equation (EQ column 3) for the F.W.D. tractor. The equation is of the form:

Opening Inv. + Production - Sales - Closing Inv. + Artificial = 0

The reduced cost indicates that if the value of the artificial variable, SFWDTMSD, is increased by 1, the objective function would increase by Ł2660.26. This is the opposite of all the rows considered so far, where increasing the slack decreased contribution. In Row 83, increasing the value of the artificial variable upsets the identity. From Row 87 it is obvious that actual sales of F.W.D.'s cannot be increased, they already equal forecast sales of 40. Since sales cannot be increased, the next most profitable course of action is to reduce production. Glancing at the inventory of F.W.D.'s from month A (PFWDTRIA, PFWDTRIB, etc., Exhibits 5.14 to 5.17), it reaches a peak in D and drops to zero in F. Obviously, the biggest cost saving from a free F.W.D. in February is to reduce production in December and thereby gain the production costs plus the inventory costs till February. The interpretation of the dual activity is that if an extra F.W.D. were made available in February, it would be possible to reduce costs by Ł2660.26, exclusive of the cost of making the product available. For instance, suppose there was spare capacity in October of the previous year, and direct labour was underemployed. The cost of making the product in October and storing until the beginning of month D would be Ŀ2459.62. Reference to the reduced cost of Column 344 PFWDTRIZ, Exhibit 5.14 tends to support the description for Row 83. The L.P. views the opening inventories as a free good. If no limits were set on their value, the model would meet the entire year's production needs by putting each opening inventory equal to the cumulative sales for the year of the corresponding product. Management is able to compare the costs incurred in 1971 by having products available at the beginning of fiscal 1972,with the savings generated in fiscal 1972. In this instance, an alternative approach to the dual activity of Ŀ2660.26 is that it is the cost of making and transferring 1 F.W.D. from December to February.

Rows 85 and 86 are similar to 83.

84 STRALMSD 361.1 The equation balances sales, production and inventories for the drill. Actual sales are less than forecast sales, Row 88, because the supply of hydraulic rams limits production. The most profitable use of a free drill is to sell it, immediately. The dual activity of Ŀ361.1 equals the sales revenue, in the L.P. model, of a drill.

87 SFWDTPSD - 1148.73722 The constraint represented is that actual sales must not be greater than forecast sales. If the value of the slack is increased, one less F.W.D. is available for sale; production is cut back simultaneously according to Row 83. Contribution, the value of the objective function, drops by Ŀ1148.73, equivalent to sales revenue minus marginal cost. This view is supported by the fact

that the dual activities for Rows 83 and 87 sum to ₤3809 - the sales revenue of an F.W.D. The dual activity of Row 87 represents the loss in contribution when one less F.W.D. is produced and sold; while that of Row 83 is the gain when a free F.W.D. is made available, permitting sales to be maintained and production to be reduced. As a dual activity, ₤1148.74 is the increase in contribution from the production and sale of 1 more unit. Thus, if gaining an extra sale, by salesman incentive or customer discount, costs less than ₤1148.74, the company is still in-pocket on the deal.

Rows 89 and 90 are similar to 87.

88 STRALPSD Zero Since there are unfilled orders for drills, an extra order is worth nothing. Actual sales would remain at 120.88, limited by the supply of rams.

91 SHTRTTCD 35.00 Together with 92 and 93, these are the balance equations for manpower in adjacent months. The equation for each department has the form:

$$\text{Manpower}_t - \text{Manpower}_{(t+1)} = \text{Decrease}_{(t+1)} - \text{Increase}_{(t+1)}$$

Defining variables for Decrease and Increase make it possible to limit the rate of change (Rows 94 to 99) as well as include the costs of changing. The significance of the dual activity is that if an extra trained man was made available in February, contribution would be increased by ₤35.0, (saving the cost of hiring and training 1 man in the primary department). Since the department is at the limit of existing facilities, Exhibit 5.16 Row 444 DHTRTTND, there are no other savings. The dual activity for the assembly department, Row 93 SASSLYCD, has the same explanation. The situation in the welding department, Row 92 SWELDGCD, is more complicated. The schematic on the next page, Exhibit 5.20, shows the input coefficients and output values of activities and dj's for the relevant section of the matrix. The increase in size of the welding department between months C and D is the maximum permitted by Row 95 SWELDGUD (UL), and the department is still below the capacity of existing equipment, Exhibit 5.16, Column 448 DWELDGND. Increasing the value of the variable SASSLYCD is equivalent to adding a free (no hiring or training costs) man and bypassing the restriction imposed by Row 95 SWELDGUD, because the value of DWELDGUD is unaffected. The result of the addition of a free man would be to increase contribution by Ŀ184.66. The mechanics of the calculation are given below in Exhibit 5.19.

DUAL ACTIVITY FOR SWEDLGCD

			Ŀ	
1.	Increase DWELDGND, DWELDGXD and DWELDGZD by 1 man	- Spend	106.8	129.85 → 130.85
2.	Decrease work subcontracted by corresponding amount	- Save	354.67	435 std. hrs.
3.	Increase the value of DWELDGDE by 0.02 x 5.0	- Spend	0.1	(2.617 - 2.597)
4.	Increase DWELDGNE by 0.98 x 99.4	- Spend	97.42	127.25 → 128.23
5.	Decrease DWELDGUF by 0.98 x 35.0	- Save	34.30	(7.74 - 6.76)
			184.65	

Exhibit 5.19

Exhibit 5.20

SECTION OF MATRIX & RESULTS

FOR THE WELDING DEPARTMENT

		d.j							-189.66	-.82	-43.27	-9.52	184.66	149.66			
		COST	-82.4	-82.4	-16.8	-7.6	-287	-35	-5								
										UL	UL	UL	EQ	LL	BS		
		ACT.	121.35	129.85	129.85	129.85	14.19	8.49	0	0	0	0	0	0	-2.43		
d.j	ACT.		DNC	DND	DXD	DZD	DSD	DUD	DDD	SNGD	SXD	SZD	SCD	SUD	SDD		
.82	-	SNGD		-352	-62	-21	-352			1						=	0
43.27	-	SKD		-1	1						1					=	0
9.52	-	SZD			-1	1						1				=	0
-184.66	-	SCD	1	-1				1	-1				1			=	0
-149.66	-	SUD	.07					-1						1		=	0
0	-.283	SDD	.02						-1						1	=	0

Note: The column names omit the middle four characters - WELDG. Thus the first name represents DWELDGNC.

: Similarly for the row names.

An example of a situation in which this dual activity would be relevant is where a welder, having left for another job, applies for re-employment.

94 SHTRTTUD Zero Restrictions 94 to 99 limit the rate of change of manpower to a certain percentage of the men in each department in the previous month. Since the rate of increase in the primary department between January and February is less than the limit, expenditure on increasing the limit (better training facilities) would be wasted. In the welding department, Row 95 SWELDGUD, the maximum number of recruits has been absorbed and existing facilities have not been used up. Increasing the rate at which men could be added to the department would be worth £149.66 per man. The signs of the coefficients in row SWELDGUD, Exhibit 5.20, account for the unexpected sign of the dual activity. The saving is lower than the addition of a free man, Row 92, by the amount of the existing advertising and training costs, £35. In other words, management could afford to pay up to a total of £184.66 (£149.66 + £35) to get an extra man working in the welding department in February; for instance, by assigning an apprentice with the appropriate skills to the department for three months on-the-job training. The value of inducing higher rates of redundancies, Row 97 to 99, is zero as the need is for more men not less.

5.2.2. Columns Section

Exhibits 5.15 and 5.16 supply the reduced costs of structural variables in month D.

432 PFWDTRPD 76.89235 Production of the F.W.D. tractor is restrained by the capacity of its special purpose equipment. The reduced cost indicates that if the capacity were increased to make one more unit in February, contribution would improve by £76.89. Since the annual capacity is sufficient, management could explore the possibility of a productivity deal or working Saturday and Sunday afternoons.

Columns 434 and 435 are the same as 432.

433 PTRALRPD zero Since production of the drill is limited by the supply of rams there is no need for additional capacity on jigs and fixtures.

436 MFWDTRPD zero Variables 436 to 439 are the actual sales. The latter are determined on the one hand by production and inventory, and on the other by forecast sales. The reduced costs of production and inventory indicate the returns from increasing actual sales when these are below forecast sales. The dual activity of the appropriate row is the value of increasing forecast sales when actual sales equal forecast sales.

440 PFWDTRID zero For the present policy option, apart from the first and last months, there are no limits on finished machines inventory other than the implicit ones of zero and infinity. Therefore, from months A-L, inventory will only have a reduced cost when it is at its lower limit of zero. In month D, the reduced cost for Column 441 PTRALRID is -3.2. In other words, changing the number of drills in stock from zero to 1 will reduce contribution by the holding cost.

444 DHTRTTND 104.38817 The variable represents the number of men in the primary department. The existing facilities are one

restriction on the number of men who can be employed. In the present case, this limit has been reached. The reduced cost indicates that bringing in one more man would increase contribution by £104.39. Two possibilities are increasing the proportion of men on nights from the current 40%, and investing in new equipment. The reduced costs can be used to calculate the return on the latter course of action. The reduced cost for Column 452 has a similar interpretation but is of less consequence. Column 448 has a reduced cost of zero because the existing facilities are not fully utilised, and the active restraint is Row 95, limiting the rate of increase. The dual activity of Row 95 shows the saving from relaxing the restriction on the rate of increase.

445 DHTRTTXD zero The variable for the number of men working overtime at 1 1/2. They are limited to the number employed for normal time, Column 444. The corresponding dual activity in the Rows Section indicates the change in the objective function from a less severe restriction. Column 446 DHTRTTZD refers to Sunday overtime. Its corresponding dual activity is found in Row 79 SHTRTTZD.

447 DHTRTTSD zero There are no restrictions on the number of standard hours that can be subcontracted.

Columns 448 to 455 repeat the sequence for the welding and assembly departments.

456 DHTRTTUD zero Variables 456 to 458 represent the number of men added to the respective departments since the previous month. There are no upper bounds on these variables, therefore no reduced costs. Their values are restricted by equations 94 to 96. The dual activities for these rows indicate the value of having higher rates of change from one month to the next.

459 DHTRTTDD -40.0 Variables 459 to 461 represent the number of men leaving the departments. The implicit lower bounds are zero. The reduced cost indicates that if 1 man left the primary department, contribution would be down by £40.0. Exhibit 5.21 explains the calculation for the welding department. Reference back to Exhibits 5.19 and 5.20 will reveal how closely related are the reduced costs and the dual activities of the corresponding row.

From the discussion in 5.2.1. and 5.2.2. it is seen that the dual activities of the rows, which represent either balance equations or restrictions on the supply of or demand for capacity, measure the value of relaxing the active constraints. While the reduced costs of the structural variables which are at upper or lower bound are the changes in contribution for unit changes in the bounds. Management is thus able to analyse the profit improvement from marginal changes in the capacity of existing general and special purpose facilities, from pursuing different manpower policies and so on. Section 6 provides information on the range over which the reduced costs are valid, i.e. on the number of units which can be shifted at a given marginal cost/unit.

REDUCED COST FOR DWELDGDD

The consequences of increasing the activity value of DWELDGDD from zero to 1 are:

			£
1	Increase the value of DWELDGDD by 1	- Spend	5.00
2	Decrease DWELDGND, DWELDGXD and DWELDZD by 1	- Save	106.80
3	Increase the standard hours sub-contracted, DWELDGSD to offset 2	- Spend	354.67
4	Decrease the number of men leaving the department DWELDGDE by .02	- Save	0.1
5	Decrease DWELDGND by 0.98, fewer men in the department	- Save	97.41
6	Increase DWELDGUF, as more men are hired, by 0.98	- Spend	34.30
			-189.66

Exhibit 5.21

6. POST-OPTIMAL RESULTS

There are four parts to the post-optimal output. Sections 1 and 3 are for rows, and Sections 2 and 4 for columns. One example of each is included as Exhibits 5.22 to 5.25. The structure is the same as sections 3.0 and 4.0, description followed by explanation. The description is not the same for rows and columns.

The MPS/360 program assumes a cost minimisation problem. Hence the output refers to input costs, upper cost, etc. The formulation being discussed here is for maximisation. To retain compatibility I adopt the MPS/360 terminology. Although a mental correction is needed for some of the headings, this is not necessary for the figures. Costs are negative, savings are positive.

6.1. Sections 1 and 3 - Rows Sections

Exhibits 5.22 and 5.23 refer to rows at their limit levels and rows at intermediate level respectively.

NUMBER. The internal serial number of the row.

ROW. The name given to the row by the user.

AT. A two-character code denoting the status that the row activity has in the solution. Codes and their meanings are as follows:

BS - row activity at intermediate level

EQ - row activity at fixed level

UL - row activity at upper level

LL - row activity at lower level

Exhibit 5.22

FACTORY STRIKE IN MARCH

NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT. ..UPPER LIMIT.	LOWER ACTIVITY UPPER ACTIVITY	...UNIT COST.. ...UNIT COST..	..UPPER COST.. ..LOWER COST..	LIMITING PROCESS.	AT
78	SASSLYXD	UL	.	.	NONE .	55.00000- 7.77853	50.80833- 50.80833		DASSLYXD DASSLYSD	LL LL
79	SHTRTTZD	UL	.	.	NONE .	29.99998- 19.34048	8.95539- 8.95539		DHTRTTZD DHTRTTSD	LL LL
80	SWELDGZD	UL	.	.	NONE .	129.85455- 237.93202	9.52216- 9.52216		DWELDGZD DWELDGSD	LL LL
81	SASSLYZD	UL	.	.	NONE .	55.00000- 30.78999	11.40000- 11.40000		DASSLYZD DASSLYSD	LL LL
82	SHYDRAMD	UL	820.00000	.	NONE 820.00000	808.99856 887.11934	66.80673- 66.80673		DASSLYSD PTRALRPD	LL UL
83	SFWDTMSD	EQ	.	.	. .	7.60795- 7.00000	2660.26266 2660.26256-		DASSLYSD PFWDTRPB	LL UL
84	STRALMSD	EQ	.	.	. .	69.11934- 120.88014	361.09999 361.09999-		STRALPSD MTRALRPD	UL LL
85	SLOADMSD	EQ	.	.	. .	50.42540- 14.14007	355.46228 355.46228-		PLOADRPB DASSLYSD	LL LL
86	SDIGGMSD	EQ	.	.	. .	1.99013- 14.00002	805.58825 805.58825-		SHYDRAMA PDIGGRPA	UL UL
87	SFWDTPSD	UL	40.00000	.	NONE 40.00000	32.39205 47.00000	1148.73711- 1148.73711		DASSLYSD PFWDTRPB	LL UL
89	SLOADPSD	UL	118.00000	.	NONE 118.00000	67.57450 132.14007	54.28758- 54.28758		PLOADRPB DASSLYSD	LL LL
90	SDIGGPSD	UL	237.00000	.	NONE 237.00000	235.00937 251.00002	381.81141- 381.81141		SHYDRAMA PDIGGRPA	UL UL
91	SHTRTTCD	EQ	.	.	. .	1.66170- 1.45551	34.99999 34.99999-		DHTRTTUD SHTRTTUD	LL LL
92	SWELDGCD	EQ	.	.	. .	5.14544- 1.11147	184.66129 184.66129-		DWELDGND SWELDGUF	UL LL
93	SASSLYCD	EQ	.	.	. .	.55000- 4.89500	109.99999 109.99999-		DASSLYUD SASSLYUD	LL LL
95	SWELDGUD	LL	.	.	129.85456 5.14544 135.0 . NONE	5.14544- 1.11147	149.66128 149.66128-	INCREASING ACTIVITY DECREASES SWELDGUD	DWELDGND SWELDGUF	UL LL
110	SFWDTMSE	EQ	.	.	. .	7.60795- 7.00000	2697.06262 2697.06262-		DASSLYSD PFWDTRPB	LL UL

LEAVES BASIS

Exhibit 5.23

ECOLE DES MINES DE PARIS

SECTION 3 - ROWS AT INTERMEDIATE LEVEL

NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT. ..UPPER LIMIT.	LOWER ACTIVITY UPPER ACTIVITY	...UNIT COST.. ...UNIT COST..	..UPPER COST.. ..LOWER COST..	LIMITING PROCESS.	AT AT
10	SHYDRAMA	BS	196.88727	3.11273	NONE 200.00000	173.94507 235.34149	1.98430- 3.23159-		SHTRTTZA DHTRTTSA	UL LL
28	SHYDRAMB	BS	345.35970	74.64030	NONE 420.00000	334.08332 356.35103	17.07086- 1.82873-		FDIGGRPC DASSLYSA	UL LL
43	SHTRTTDB	BS	.23000	.23000-	. NONE	.95132- .23000	550.67233- INFINITY-		DHTRTTDB NONE	LL
44	SWELDGDB	BS	2.12000	2.12000-	. NONE	1.14920 2.12000	746.93535- INFINITY-		DWELDGDB NONE	LL
45	SASSLYDB	BS	.45000	.45000-	. NONE	2.65840- .45000	722.78210- INFINITY-		DASSLYDB NONE	LL
55	SHYDRAMC	BS	575.11986	44.88014	NONE 620.00000	555.22250 586.12119	28.29205- .		SASSLYZB DASSLYSC	UL LL
61	STRALPSC	BS	132.11986	57.88014	NONE 190.00000	63.00003 143.12119	3.20000- .		PTRALRIC DASSLYSC	LL LL
70	SHTRTTDC	BS	.25530	.25530-	. NONE	1.05597- .25530	271.76775- INFINITY-		DHTRTTDC NONE	LL
71	SWELDGDC	BS	2.26840	2.26840-	. NONE	1.22954 2.26840	448.01069- INFINITY-		DWELDGDC NONE	LL
72	SASSLYDC	BS	.49500	.49500-	. NONE	3.95500- .49500	406.40828- INFINITY-		DASSLYDC NONE	LL
88	STRALPSD	BS	120.88016	69.11984	NONE 190.00000	109.87832 252.99998	. 3.20000-		DASSLYSC PTRALRIC	LL LL
94	SHTRTTUD	BS	1.45551	1.45551-	. NONE	1.17213 1.45306	39.99999- 104.38818-		DHTRTTDD DHTRTTND	LL UL
96	SASSLYUD	BS	4.89500	4.89500-	. NONE	4.35050 5.42376	114.99999- 15.90899-		DASSLYDD DASSLYND	LL UL
97	SHTRTTDD	BS	.28338	.28338-	. NONE	1.17213- .28338	39.99999- INFINITY-	INCREASING ROW ACTIVITY DECREASES CORRESPONDING STRUCTURAL VARIABLE	DHTRTTDD NONE	LL
98	SWELDGDD	BS	2.42719	2.42719-	. NONE	1.31572 2.42719	189.66129- INFINITY-		DWELDGDD NONE	LL
99	SASSLYDD	BS	.54450	.54450-	. NONE	4.35050- .54450	114.99999- INFINITY-		DASSLYDD NONE	LL

ENTERS BASIS

FACTORY STRIKE IN MARCH

ECOLE DES MINES DE PARIS

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT. ..UPPER LIMIT.	LOWER ACTIVITY UPPER ACTIVITY	...UNIT COST.. ...UNIT COST..	..UPPER COST.. ..LOWER COST..	LIMITING PROCESS.	AT AT
404	PLOADRPC	UL	123.99992	188.97011-	. 123.99993	38.62454 174.42529	3.08745- 3.08745	192.05756- INFINITY	DHTRTTSC PLOADRPB	LL LL
405	PDIGGRPC	UL	250.99996	598.38998-	. 250.99997	236.99994 252.99009	13.74920- 13.74920	612.13918- INFINITY	PDIGGRPA SHYDRAMA	UL UL
411	PTRALRIC	LL	.	3.20000-	. NONE	57.88014- 69.11934	3.20000 3.20000-	INFINITY- .	STRALPSC STRALPSD	UL UL
425	DASSLYSC	LL	.	322.99983-	. NONE	6.57953- 1.81118	. .	INFINITY- 322.99945-	DHTRTTSC DASSLYSD	LL LL
429	DHTRTTDC	LL	.	5.00000-	. NONE	1.66170- .25530	271.76777 271.76777-	INFINITY- 266.76777	DHTRTTUD SHTRTTDC	LL LL
430	DWELDGDC	LL	.	5.00000-	. NONE	4.80832- 1.03876	448.01071 448.01071-	INFINITY- 443.01071	DWELDGND SWELDGUF	UL LL
431	DASSLYDC	LL	.	5.00000-	. NONE	.55000- .49500	406.40830 406.40830-	INFINITY- 401.40830	DASSLYNC SASSLYDC	UL LL
432	PFWDTRPD	UL	50.00000	2340.11973-	. 50.00000	43.00000 72.03578	76.89233- 76.89233	2417.01205- INFINITY	PFWDTRPB DHTRTTSB	UL LL
434	PLOADRPD	UL	123.99992	188.97011-	. 123.99993	81.31787 174.42529	6.28745- 6.28745	195.25756- INFINITY	DHTRTTSD PLOADRPB	LL LL
435	PDIGGRPD	UL	250.99996	598.38998-	. 250.99997	236.99994 252.99009	23.54921- 23.54921	621.93919- INFINITY	PDIGGRPA SHYDRAMA	UL UL
441	PTRALRID	LL	.	3.20000-	. NONE	. 107.99999	3.20000 3.20000-	INFINITY- .	MTRALRPE STRALPSE	LL UL
444	DHTRTTND	UL	29.99999	82.39996-	. 29.99999	29.99244 30.12126	104.38818- 104.38818	186.78814- INFINITY	SASSLYDI SASSLYDK	LL LL
452	DASSLYND	UL	55.00000	82.39998-	. 55.00000	54.47103 55.02125	15.90899- 15.90899	98.30898- INFINITY	DASSLYDI SASSLYDI	LL LL
459	DHTRTTDD	LL	.	5.00000-	. NONE	1.66170- .28338	39.99999 39.99999-	INFINITY- 34.99999	DHTRTTUD SHTRTTDD	LL LL
460	DWELDGDD	LL	.	5.00000-	. NONE	5.14544- 1.11147	189.66130 189.66130-	INFINITY- 184.66130	DWELDGND SWELDGUF	UL LL
461	DASSLYDD	LL	.	5.00000-	. NONE	.55000- .54450	115.00000 115.00000-	INFINITY- 110.00000	DASSLYUD SASSLYDD	LL LL
462	PFWDTRPE	EQ	.	2340.11999-	. .	7.00000- 7.60795	356.94279- 356.94279	2697.06278- INFINITY	PFWDTRPB DASSLYSD	UL LL

LEAVES BASIS

Exhibit 5.24

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT. ..UPPER LIMIT.	LOWER ACTIVITY UPPER ACTIVITY	...UNIT COST.. ...UNIT COST..	..UPPER COST.. ..LOWER COST..	LIMITING PROCESS.	AT AT
437	MTRALRPD	BS	120.88014	361.10002	. NONE	109.87830 189.99996	. 3.20000-	361.10002 364.30001	DASSLYSC PTRALRIC	LL LL
438	MLOADRPD	BS	117.99999	409.75002	. NONE	67.57450 117.99999	54.28759- INFINITY-	355.46243 INFINITY	SLOADPSD NONE	UL
439	MDIGGRPD	BS	236.99999	1187.39995	. NONE	235.00936 236.99999	381.81143- INFINITY-	805.58852 INFINITY	SDIGGPSD NONE	UL
440	PFWDTRID	BS	53.00000	36.60000-	. NONE	45.39205 60.00000	1066.03728- 325.77233-	1102.83728- 288.97283	SFWDTPSF PFWDTRPF	UL UL
442	PLOADRID	BS	126.99999	3.20000-	. NONE	109.99999 135.08219	47.08758- 137.50759-	50.28758- 134.30769	SLOADPSF PLOADRPF	UL UL
443	PDIGGRID	BS	258.99998	9.60000-	. NONE	257.00936 264.65208	372.01150- 164.74167-	381.81150- 154.94167	SDIGGPSE PDIGGRIE	UL LL
445	DHTRTTXD	BS	29.99998	16.80000-	. NONE	. 29.99998	40.16797- INFINITY-	56.96797- INFINITY	SHTRTTXD NONE	UL
446	DHTRTTZD	BS	29.99998	7.60000-	. NONE	INFINITY- 29.99998	8.95589- INFINITY-	16.55589- INFINITY	SHTRTTZD NONE	UL
447	DHTRTTSD	BS	1.16861	273.99997-	. NONE	.52515 1.17734	. 84.48040-	273.99997- 189.51957-	DASSLYSC DHTRTTND	LL UL
448	DWELDGND	BS	129.85455	82.39999-	. 135.00000	128.74308 129.85455	149.66129- INFINITY-	232.06128- INFINITY	SWELDGUD NONE	LL
449	DWELDGXD	BS	129.85455	16.80000-	. NONE	. 129.85455	43.27330- INFINITY-	60.07330- INFINITY	SWELDGXD NONE	UL
450	DWELDGZD	BS	129.85455	7.60000-	. NONE	INFINITY- 129.85455	9.52216- INFINITY-	17.12216- INFINITY	SWELDGZD NONE	UL
451	DWELDGSD	BS	14.19481	286.99994-	. NONE	12.64452 15.55836	. 121.10527-	286.99994- 165.89467-	DASSLYSC SWELDGUD	LL LL
453	DASSLYXD	BS	55.00000	16.80000-	. NONE	54.47104 55.00000	15.90899- INFINITY-	32.70899- INFINITY	DASSLYND NONE	UL
454	DASSLYZD	BS	55.00000	7.60000-	. NONE	INFINITY- 55.00000	11.40000- INFINITY-	19.00000- INFINITY	SASSLYZD NONE	UL
455	DASSLYSD	BS	1.81118	322.99983-	. NONE	1.47815- 2.45330	. 12.90431-	322.99983- 310.09552-	DASSLYSC DASSLYND	LL UL
456	DHTRTTUD	BS	1.66170	34.99999-	. NONE	1.65415 1.94506	104.38818- 39.99999-	139.38817- 5.00000	DHTRTTND DHTRTTDD	UL LL

ENTERS BASIS

Exhibit 5.25

ACTIVITY. The value that the row activity has in the solution. It is computed from $b_i - l_i$, where b_i is the R.H.S. and l_i is the logical variable.

SLACK ACTIVITY. The value of the associated slack variable.

The upper line for each row shows the activity-cost relationship for activity decrease/cost increase:

LOWER LIMIT. The input lower limit (specified or implicit) for this row.

LOWER ACTIVITY. The level to which the row activity may be decreased at a cost per unit of decrease given by UNIT COST. Decrease beyond this level has a different cost per unit of decrease. The input row lower limit is ignored.

UNIT COST. The change in the objective function per unit of decrease in row activity. The problem can be modified to decrease the row activity level as far as LOWER ACTIVITY, at this cost per unit of decrease.

LIMITING PROCESS. The name of the row or column that would change its status if the activity level of this row were decreased below LOWER ACTIVITY: Section 1. LIMITING PROCESS will leave the basis. Section 3. LIMITING PROCESS will enter the basis.

AT. The status associated with LIMITING PROCESS:

LL - leaves or enters basis at lower limit.

UL - leaves or enters basis at upper limit.

The lower line for each row shows the activity-cost relationship for activity increase/cost decrease:

UPPER LIMIT. The input upper limit (specified or implicit) for this row.

UPPER ACTIVITY. The level to which the row activity may be increased at a cost per unit of increase given by UNIT COST. Increase beyond this level has a different cost per unit of increase. The input row upper limit is ignored.

UNIT COST. The change in the objective function per unit of increase in row activity. The problem can be modified to increase the row activity level as far as UPPER ACTIVITY, at this cost per unit of increase.

LIMITING PROCESS. The name of the row or column that would change its status if the activity level of this row were increased above UPPER ACTIVITY: Section 1. LIMITING PROCESS will leave the basis. Section 3. LIMITING PROCESS will enter the basis.

AT. The status associated with LIMITING PROCESS.

LL - leaves or enters basis at lower limit.

UL - leaves or enters basis at upper limit.

Before going on to Sections 2 and 4 for Columns, there are a few comments about the significance of the information in the Rows Sections.

Firstly, the data refer to the row activity and not the slack activity: the converse of Exhibits 5.11 to 5.13.

Secondly, LIMITING PROCESS and AT help identify the mechanism which generated the marginal cost and the consequences of changing the row activity. When formulating policies it is useful to know both the change in contribution and the compensating changes in activity values which will occur. For instance, increasing the forecast sales of F.W.D.'s, Row 87 SFWDTPSD, from 40 to 47 would cause production of F.W.D.'s in December to be increased to the limit of the capacity of special purpose equipment.

Thirdly, the difference between ACTIVITY and UPPER ACTIVITY (or LOWER), multiplied by UNIT COST gives the total change in contribution caused by increasing (decreasing) the activity of the row from its present value to UPPER ACTIVITY, i.e. in the case of F.W.D.'s (Row 87), gaining 7 more sales in February would increase contribution by about Ł8,000.

Fourthly, in Section 3, Exhibit 5.23, since the logical variables are in the basis, increasing or decreasing their values will reduce total contribution (if it was possible to increase contribution by changing the value of a logical variable, presently in the basis at intermediate level, the solution would not be optimal). There is no reason why the cost penalty from changing the row activity should be symmetric, and, in fact, it is not.

6.2. Sections 2 and 4 - Columns Sections

The relevant exhibits are 5.24 and 5.25.

NUMBER. The internal serial number of the column.

COLUMN. The name given to the column by the user.

AT. A two-character code denoting the status that the column activity has in the solution. Codes and their meanings are as follows:

BS - in the basis

FR - nonbasic, free

EQ - nonbasic, artificial

UL - nonbasic, at upper level

LL - nonbasic, at lower level

ACTIVITY. The value that the column activity has in the solution.

INPUT COST. the unit cost of this variable, as specified by the user.

The upper line for each column shows the activity-cost relationship for activity decrease/cost increase:

LOWER LIMIT. The input lower bound (specified or implicit) for this column.

LOWER ACTIVITY. The activity level that would result from a cost coefficient increase from INPUT COST to UPPER COST. The specified lower bound is ignored.

UNIT COST. The change in the objective function per unit of decrease in activity level down to LOWER ACTIVITY. The problem can be modified to decrease the solution activity level as far as LOWER ACTIVITY at this cost per unit of decrease.

UPPER COST. The highest cost coefficient at which the variable would be maintained at its ACTIVITY. If the cost coefficient increased above UPPER COST, the activity level would decrease to LOWER ACTIVITY.

LIMITING PROCESS. The name of the row or column that would change its status if the activity level of this variable were decreased below LOWER ACTIVITY: Section 2. LIMITING PROCESS will leave the basis. Section 4. LIMITING PROCESS will enter the basis.

AT. The status associated with LIMITING PROCESS:

LL - leaves or enters the basis at lower limit.

UL - leaves or enters the basis at upper limit.

The lower line for each column shows the following activity-cost relationships for activity increase/cost decrease:

UPPER LIMIT. The input upper bound (specified or implicit) for this column.

UPPER ACTIVITY. The activity level that would result from a cost coefficient decrease from INPUT COST to LOWER COST. The specified upper bound is ignored.

UNIT COST. The change in the objective function per unit of increase in activity level up to UPPER ACTIVITY. The problem can be modified to increase the solution activity level as far as UPPER ACTIVITY at this cost per unit of increase.

LOWER COST. The lowest cost coefficient at which the variable would be maintained at its ACTIVITY. If the cost coefficient decreased below LOWER COST, the activity level would increase to UPPER ACTIVITY.

LIMITING PROCESS. The name of the row or column that would change its status if the activity level of this variable were increased above LOWER ACTIVITY: Section 2. LIMITING PROCESS will leave the basis. Section 4. LIMITING PROCESS will enter the basis.

AT. The status associated with LIMITING PROCESS:

LL - leaves or enters the basis at lower limit.

UL - leaves or enters the basis at upper limit.

Some of the points of interest are:

Firstly, the difference between INPUT COST and UPPER COST is a measure of the insensitivity of the ACTIVITY to cost increases. Thus, for Column 452 DASSLYND, the optimal solution is unchanged for an INPUT COST anywhere between ₤82.49 and ₤98.3. Or, to put it another way, if labour costs in the assembly department deteriorated by up to 19%, the manpower plan would remain unchanged. Similarly, the difference between INPUT COST and LOWER COST measures the range of insensitivity to cost decreases. In this case, if men paid for the right to work in the assembly department in February, only 55.02 would be employed. The conclusion from this information is that the number of men required in the assembly department is relatively insensitive to changes in wage rates and that investment in new capital equipment should not be one of management's priorities.

Secondly, the difference between ACTIVITY and UPPER ACTIVITY (or LOWER ACTIVITY), times UNIT COST, gives the total change in contribution obtainable at the rate/unit given by UNIT COST. So, for Column 434 PLOADRPD, if production were increased from 124 to 174.4, the total increase in contribution would be about ₤300. In fact, production of the loader is limited by special purpose equipment. Investment to increase the capacity of such equipment for the loader by 40% would generate a saving of ₤300 in February alone.

Thirdly, the difference between UPPER COST and LOWER COST, for a given variable, indicates the range of INPUT COST over which the optimal solution would remain unchanged.

Fourthly, the difference between LOWER ACTIVITY and UPPER ACTIVITY indicates the consequences of INPUT COST drifting outside the range between UPPER COST and LOWER COST. If INPUT COST exceeds the limits of UPPER or LOWER COST, ACTIVITY will take on the value of LOWER or UPPER ACTIVITY respectively and there will be a change of basis. The variable changing its status is given in the column LIMITING PROCESS. Thus, UPPER and LOWER ACTIVITY give the range of ACTIVITY over which there will be no change of basis.

6.3. Explanation

Just one example is taken from each of the four Exhibits 5.22 to 5.25 to illustrate the significance of the figures. The row or column number comes first, and then the name of the logical or structural variable.

82 SHYDRAMD, Exhibit 5.22. The restriction limits cumulative production of drills and loaders to the cumulative supply of hydraulic rams. The row ACTIVITY is 820, the same as the UPPER LIMIT, and the SLACK ACTIVITY is zero. This means that to the end of February, cumulative production equals cumulative supply. The figure of 887.12 under UPPER ACTIVITY signifies that production is being restrained by lack of rams. The difference between the row ACTIVITY of 820 and the

UPPER ACTIVITY of 887 gives the number of extra rams which could be used. The bottom UNIT COST is the positive figure ₤66.8. Contribution would be increased by ₤66.8 for each extra ram supplied, up to a maximum of 67 additional rams. Only 67 are required because that is the number of extra drills which can be made in February before the limit imposed by jigs and fixtures is reached (production is currently 121, the upper limit 188, Exhibit 5.15). Supplying more than 67 additional rams in February would be of no help. The lost sales in earlier months cannot be redeemed. After March the supply of rams keeps pace with demand. Under LIMITING PROCESS, the bottom entry is PTRALRPD (production of drills in February). It is at UL. Consequently when the cumulative supply of drills reaches 887, the production of drills will be at upper limit and further rams redundant. The report thus confirms the analysis based on the full optimal results in Exhibit 5.15.

The total saving from extra rams is the saving/unit (₤66.8) times the number of units (887 - 820), giving ₤4476. Management now has some idea of the premium it would be worth paying to obtain an extra 67 rams by, for instance, finding another source, or diverting them from another customer. The 808.999 under LOWER ACTIVITY is the level to which cumulative delivery could drop at a cost/unit of ₤66.8. Therefore, management has a guide to the consequences of deliveries falling below their present inadequate level. When deliveries are down to 809, workload in assembly would have dropped far enough to remove the need for subcontracting (LIMITING PROCESS : DASSLYSD; AT : LL).

94 SHTRTTUD, Exhibit 5.23. The restriction limits the rate of increase of manpower in the primary department. It has the form:

kDHTRTTND $\geq$ DHTRTTUD (where k = 0.11)

The figure 1.45551 under ACTIVITY is the row activity, in this case kDHTRTTNC - DHTRTTUD. As can be verified from Exhibit 5.15 and 5.16, DHTRTTUD has a value of 1.66170 and DHTRTTNC of 28.34. Thus, the matrix coefficients of the optimum solution are derived:

28.34 $\times$ .11 - 1.66170 + SHTRTTUD = 0

3.1174 - 1.66170 + SHTRTTUD = 0

1.4553 + SHTRTTUD = 0

The UNIT COST is the change in the objective function per unit change in row activity. The lower line is for increases in row activity.

Increasing row activity (equivalent to adding a small amount to the R.H.S.) decreases the value of DHTRTTUD. And vice versa for decreasing row activity. Therefore, increasing the number of men added to the primary department in February increases costs by £115. Conversely, reducing the number of men added to the department increases costs by only £16. The reason why moves in neither direction increase contribution is because moves away from optimal activity by a variable in the basis cannot be beneficial.

432 PFWDTRPD, Exhibit 5.24. The column variable represents the number of F.W.D.'s produced in February. The fact that the entry for ACTIVITY is the same as that for UPPER LIMIT indicates that production is being held back by jigs and fixtures. The difference between 72.03578 (UPPER ACTIVITY) and 50.0 (ACTIVITY) is the number of units which could be produced at a saving/unit given by the bottom UNIT COST of £76.9, i.e.

a total saving of Ŀ1694. The UPPER LIMIT is ignored. When production reaches 72, DHTRTTSB leaves the bais at lower limit, LL. In other words, the effect of increasing production in February, without a corresponding increase in sales, is to reduce production in December. The INFINITY, under LOWER COST, means that however small the cost of one F.W.D., no more than 50 would be made. The UPPER COST of - Ŀ2417.0 is the maximum to which INPUT COST could rise and ACTIVITY remain at its present value of 50. If INPUT COST rose above UPPER COST, ACTIVITY would fall to LOWER ACTIVITY (43). The ratio of UPPER and LOWER COST to INPUT COST measures the insensitivity of the optimal solution to changes in input costs.

446 DHTRTTZD, Exhibit 5.25. The column variable represents the number of men working Sunday overtime in the primary department. Row 79, SHTRTTZD, limits those working Sunday to those working Saturday. The logical variable SHTRTTZD is at its lower limit. The number working Saturday is 29.9 (Column 445 above). The LOWER LIMIT is zero (implicit bound). There is no explicit upper limit; it is provided via SHTRTTZD by DHTRTTXD. Taking UPPER LIMIT, UPPER ACTIVITY, etc. first: since ACTIVITY equals UPPER ACTIVITY there is no possibility of an increase in activity whatever the LOWER COST. For LOWER LIMIT, etc.: if the INPUT COST rose above UPPER COST, DHTRTTZD would immediately drop to zero and the whole of Sunday overtime work would be subcontracted. There are two reasons: firstly -Ŀ16.65 represents a cost per standard hour as expensive as subcontracting, Ŀ0.83. Secondly, once the internal cost exceeds that of subcontracting there is no profit motive for retaining any work for Sunday. SHTRTTZD, which was at upper limit level, immediately enters the basis at UL. The UNIT COST of -Ŀ8.96 is the increase in cost per unit decrease in ACTIVITY.

The four Exhibits 5.26 to 5.29, summarise the data for February under the headings of: penalties of deviation from planned activity levels (2 exhibits), robustness to cost changes, profit improvement.

Two of the questions one can ask about an optimal solution are:

. What changes can be made without affecting activity levels?

. What changes can be made without affecting the basis?

In planning terms these correspond to enquiring about the room for manoeuvre on the one hand without changing either the components (F.W.D. production in February) or their activity (50), and on the other without changing the components (the F.W.D. will be produced in February, but not 50 of them).

Of the analyses performed so far, penalties of deviation and profit improvement assume no alteration in the basis, and robustness assumes no change to the activities.

The entries for UPPER and LOWER ACTIVITY are the limits of ACTIVITY change which will not require a basis change. Moreover, the figures are only valid on a one-at-a-time basis; that is, they assume that everything other than the figure being changed is constant, apart from the value of the objective function. Consequently, it is not correct to add up a series of reduced costs and draw conclusions about the results of simultaneous changes.

To explore the consequences of making simultaneous changes, parametric programming should be used. MPS/360 allows parametric programming of the R.H.S. and objective function individually or together. Such analyses usually require basis changes. Two examples of their use would be to investigate the results of actual sales being 5%, 10% and 15% below forecast, and of actual costs being similarly above estimates. Changes in bounds and matrix coefficients are more difficult to make, but still easy enough to be practical.

Thus there are several extensions to L.P., of direct relevance to planning, which I have not included, because to do so would mean more exhibits and tedious comparison of results from one page to another, and so on.

Exhibit 5.26

PENALTIES OF DEVIATIONS FROM PLAN: LOGICAL VARIABLES

	POTENTIAL SALES UP (£)	POTENTIAL SALES DOWN (£)	RAM UP (£)	RAM DOWN (£)
F.W.D.	x1148.7	-1148.7		
DRILL	-3.2	nil	x66.8	-66.8
LOADER	x 54.3	-54.3		
DIGGER	x 381.8	-381.8		

Notes: (1) x indicates the activity to be at limit level.

(2) Costs have a negative sign.

(3) The figures relate to changes in requirements for or availability of resources.

(4) The important figures are the negative ones; activity levels cannot exceed limit levels. The positive figures are used in Exhibit 5.29.

	STANDARD HOURS UP (£)	STANDARD HOURS DOWN (£)	AMOUNT OF OVT. AT 1 1/2 UP (£)	AMOUNT OF OVT. AT 1 1/2 DOWN (£)	AMOUNT OF OVT. AT 2 UP (£)	AMOUNT OF OVT. AT 2 DOWN (£)	NUMBER OF ADDITIONS UP (£)	NUMBER OF ADDITIONS DOWN (£)	NUMBER LEAVING UP (£)	NUMBER LEAVING DOWN (£)
PRIMARY	x 0.8	-0.8	x40.2	-40.2	x 9.0	- 9.0	- 40.0	-104.4	- 40.0	-00
SECONDARY	x 0.8	-0.8	x43.2	-43.2	x 9.5	- 9.5	x149.7	-149.7	x189.7	-00
ASSEMBLY	x 0.8	-0.8	x50.8	-50.8	x11.4	-11.4	-115.0	- 15.9	-115.0	-00

Exhibit 5.27

PENALTIES OF DEVIATIONS FROM PLAN: COLUMN VARIABLES

	ACTUAL SALES		PRODUCTION		F.M.I.	
	UP	DOWN	UP	DOWN	UP	DOWN
	£		£		£	
F.W.D.	- 00	-1148.7	x 76.9	- 76.9	-325.8	-1066.0
DRILL	-3.2	nil	- 28.3	nil	x - 3.2	3.2
LOADER	- 00	- 54.3	x 6.3	- 6.3	-137.5	- 47.1
DIGGER	- 00	- 381.8	x 23.5	- 23.5	-164.7	- 372.0

	MANPOWER		OVERTIME AT 1 1/2		OVERTIME AT 2		SUBCONTRACT	
	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN
	£		£		£		£	
PRIMARY	x 104.4	- 104.4	- 00	- 40.2	- 00	- 9.0	- 84.5	nil
SECONDARY	- 00	- 149.7	- 00	- 43.3	- 00	- 9.5	1121.1	nil
ASSEMBLY	x 15.9	- 15.9	- 00	- 15.9	- 00	- 11.4	- 12.9	nil

	ADDITIONS TO DEPT.		LEAVERS FROM DEPT.	
	UP	DOWN	UP	DOWN
	£		£	
PRIMARY	- 40.0	- 104.4	x - 40.0	40.0
SECONDARY	- 00	1 149.7	x -189.7	189.0
ASSEMBLY	-115.0	- 15.9	x -115.0	115.0

Notes: (1) x indicates activities at limit level.

(2) A cost penalty of - INFINITY is associated with variables whoseACTIVITY equals UPPER ACTIVITY, i.e. is restrained by the limits on another row or column.

(3) The positive figures are used in Exhibit 5.29; the negative ones are relevant as penalties.

Exhibit 5.28

ROBUSTNESS TO CHANGES IN INPUT COSTS

	PRODUCTION				ACTUAL SALES				F.M.I.			
	VAL.	%	VAL.	%	VAL.	%	VAL.	%	VAL.	%	VAL.	%
F.W.D.	-2417	104	INFINITY		INFINITY		2660	70	-1102	M	289	-M
DRILL	- 185	100	-156	85	364	101	361	100	-INFINITY		700	-100
LOADER	- 195	103	INFINITY		INFINITY		355	87	- 50	M	134	-M
DIGGER	- 622	104	INFINITY		INFINITY		805	68	- 381	M	155	-M

	MANPOWER				OVERTIME AT 1 1/2				OVERTIME AT 2				SUBCONTRACT			
	VAL.	%	VAL.	%	VAL.	%	VAL.	%	VAL.	%	VAL.	%	VAL.	%	VAL.	%
PRIMARY	- 187	227	INFINITY		-57	339	INFINITY		-16.5	218	INFINITY		-274	100	-190	69
SECONDARY	- 232	282	INFINITY		-60	357	INFINITY		-17	225	INFINITY		-287	100	-166	58
ASSEMBLY	- 98	119	INFINITY		-33	196	INFINITY		-19	250	INFINITY		-323	100	-310	96

	ADDITIONS TO DEPT.				LEAVERS FROM DEPT.			
	VAL.	%	VAL.	%	VAL.	%	VAL.	%
PRIMARY	- 140	M	5	-114	-INFINITY		35	-M
SECONDARY	- 185	M	INFINITY		-INFINITY		185	-M
ASSEMBLY	- 126	M	5	105	-INFINITY		110	-M

Notes: (1) VAL. stands for value, it is either UPPER or LOWER COST. % is the ratio of VAL. to INPUT COST.

(2) Costs are negative, revenues positive.

(3) M represents a large number.

(4) $\pm$ INFINITY indicates the ACTIVITY to be unaffected by changes in INPUT cost in the specified direction.

Exhibit 5.29

TOTAL PROFIT IMPROVEMENT

	POTENTIAL SALES		RAM		PRODUCTION/J & F	
	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
-	£	£	£	£	£	£
F.W.D.	1148.7	8041			76.9	1694
DRILL			66.8	4484		
LOADER	54.2	768			6.3	317
DIGGER	381.8	5345			23.5	47

	STANDARD HOURS		AMOUNT OF OVT AT 1 1/2		AMOUNT OF OVT AT 2		NUMBER OF ADDITIONS		MANPOWER/ FACILITIES	
	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
	£	£	£	£	£	£	£	£	£	£
PRIMARY	0.8	320	40.2	199	9.0	173			104.4	13
SECONDARY	0.8	4074	43.2	2605	9.5	2266	149.7	770		
ASSEMBLY	0.8	585	50.8	395	11.4	351			15.9	700

Notes: (1) Production and Manpower concern the bounds of column variables. The others are to do with availabilities of and requirement for resources.

(2) The figures ignore the specified UPPER LIMIT.

APPENDIX 6

USES

CONTENTS

USES

1. INTRODUCTION

The Tactical Planning Model has many applications. Some involve the addition of new variables and rows and the redefining of coefficients. Others can be accommodated by changing the bounds or the R.H.S. vector. With one exception, the examples which follow are in the second category.

Although most of the policies discussed originate within a single department (e.g. a sales promotion scheme by marketing), their consequences are not similarly confined. One of the roles of the planning model is to make possible a quick global view: determining the consequences not just for the function which originated the policy (which in itself may be something of an innovation), but also for the major decision variables of the whole company.

It is the global analysis which gives the departments the chance of seeing how a certain policy decision will affect them and of formulating their own inputs in time to influence the course of events ex ante instead of ex poste. One alternative to the simultaneous consideration of the inputs of all interested parties is the sequential, and often manual, planning methods of the majority of companies.

The examples in this appendix use the scaled-down model of Appendix 5, based on the data in Appendix 7. The scaling has been achieved by reducing the number of products to 4 and the departments to 3. The planning horizon of 13 months has been retained, as have all the types of restriction.

The appendix starts by outlining the 6 policy issues, then analyses each in turn and concludes with a section on using the model (as opposed to uses of it).

The sequence for evaluating the policies is: establish the planning base, incorporate the policy parameters into the model, run the modified problem, and finally compare the new results with the planning base to give the marginal effects attributable to the policy.

Only the one-page summary results, together with a comparison against the planning base, are shown for each policy. There is no analysis of the changes in robustness and so on. The objective is to illustrate some potential uses of the model and to give a brief indication of the consequences for the main decision variables.

2. SOME CORPORATE PLANNING PROBLEMS

Suppose that for the policy-making stage of planning, corporate planners have been notified of a number of issues which will be raised and for which they must supply data.

The specific issues are:

- The managing director wishes to have a finished machines inventory of zero at the end of fiscal 1971 to help window-dress the balance sheet.
- The marketing and production control departments are in sharp disagreement over the former's policy for finished machines inventory.
- The industrial relations department anticipates a strike that will close the factory, probably during March.
- Marketing are trying to develop a promotional scheme to sell more drills in the months when sales are below 90 units.
- The purchasing department have misgivings about a supplier's ability to meet the present, inadequate commitment for deliveries during fiscal 1972, and thinks that the situation could deteriorate by a further 15%.
- A new product is due to be introduced in the coming fiscal year. There are several points still outstanding; (a) should it be made-in or bought-out?, (b) how will possible errors in the volume estimates affect this decision?, and (c) does the marginal analysis for this product accurately reflect the different possibilities?.

These are not hypothetical problems. They represent some of the more frequently recurring issues with which top management at M-F were all too familiar.

The modifications to the base model necessary to accommodate the policy issues, the results of reoptimising the model and the comparison with the planning base, will be discussed in turn.

At the end of the appendix is a brief explanation of the contents of the one-page summary. Appendix 5 has a more detailed version.

Before looking at the different policies, the results of the planning base will be presented.

2.1. The Planning Base

The planning base used for these examples is the result of running the model on the data contained in Appendix 7, before the inclusion of any new action. In practice this means that (a) the only upper bounds are on the maximum size of departments and the rate of production of individual products, (b) the opening and closing inventories have been fixed (the former is not the M.D.'s zero figure), and (c) the opening manpower has been set at the figure anticipated as the result of present policies.

The results are illustrated as Exhibits 6.1 and 6.2. The latter is a schematice of the main constituents of the one-page summary. The points of interest are: no lost sales (the delivery of rams is adequate), no subcontracting, moderate overtime (on only one occasion is Sunday used) and a zero inventory in two months.

MANAGEMENT POLICY:PLANNING BASE

REPORT FOR M.D.

PLANNING PERIOD :FROM NOV '71 TO OCT '72

DATE OF . SALES FORECAST:24/05/71

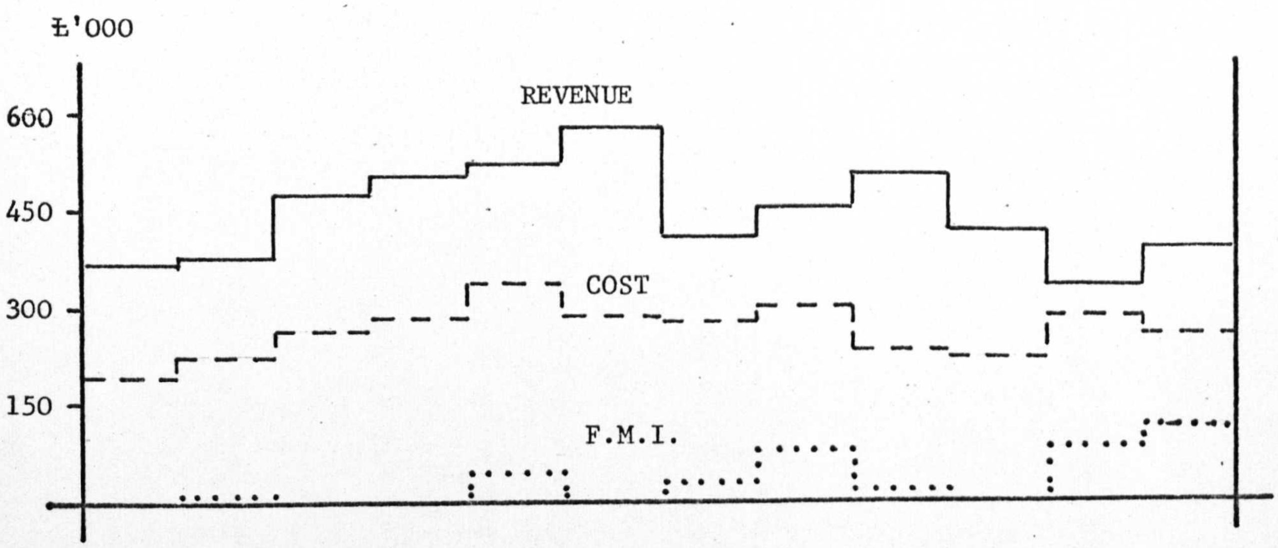
. COMPUTER RUN :06/06/71

ÉCOLE DES MINES DE PARIS

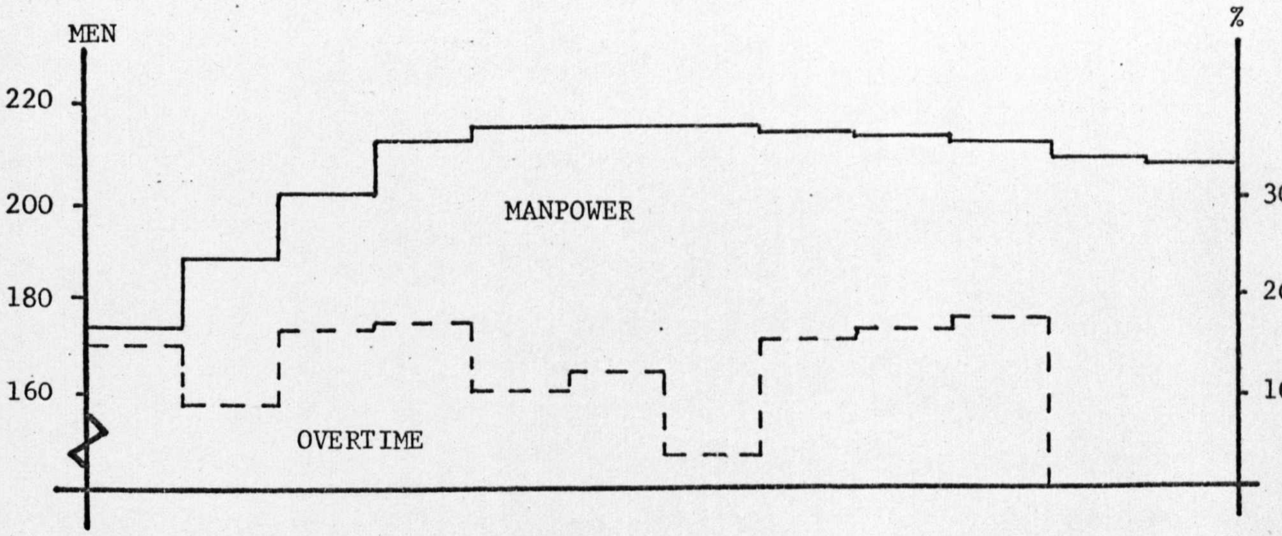
DAYS MONTH	20 NOV	22 DEC	20 JAN	20 FEB	24 MAR	19 APR	20 MAY	20 JUN	15 JUL	15 AUG	24 SEP	20 OCT	239 TOTAL
FINANCIAL SUMMARY													F'000
REVENUE	388	385	499	550	524	589	418	452	512	420	341	401	5479
COST	-160	-217	-247	-294	-348	-295	-282	-308	-239	-232	-289	-269	-3180
CONTRIBUTION	228	168	252	256	176	294	136	144	273	188	52	132	2299
F.M.I.	65	62	22		47		41	32	18		86	119	45
													F
OVTM PREMIUM	-83	-216	-1221	-3824	-2589	-2398	-943	-3256	-2630	-2646		-9	-19866
SUBCON PREMIUM													
F.M.I. HLDG	-1009	-1191	-346		-909		-633	-1534	-274		-1662	-1828	-9435
LOST SALES REV													
ACTIVITY SUMMARY													HRS'000
STANDARD HOURS	63	76	78	91	104	83	82	39	58	57	89	75	965
MADE IN	63	76	78	91	104	83	82	39	58	57	89	75	965
SUBCONTRACTED													
MANPOWER (DIRECT)	174	188	202	212	217	217	217	214	213	210	207	207	207
OVERTIME - HOURS	139	360	2035	6234	4314	3997	1571	5427	4457	4411		15	32971
- PERCENT	.50	1.09	6.28	18.35	10.33	12.09	4.53	15.37	17.50	17.50	.	.05	8.67
SALES SUMMARY - %													%
FWDT	9.82	19.79	26.72	27.70	25.44	42.03	31.89	29.49	40.92	39.90	42.45	44.64	31.73
DRILL	9.31	15.10	13.75	12.47	7.44	1.35	.35	7.91	9.24	7.31	5.29	.	7.46
LOADER	9.08	8.41	9.61	8.79	8.60	9.39	8.72	9.97	7.92	7.22	8.17	8.69	8.71
DIGGER	71.92	56.75	49.97	51.17	58.69	47.38	59.09	52.30	41.98	45.30	44.22	46.79	52.21

Exhibit 6.1

REVENUE CONTRIBUTION & F.M.I.



MANPOWER & OVERTIME



STANDARD HOURS

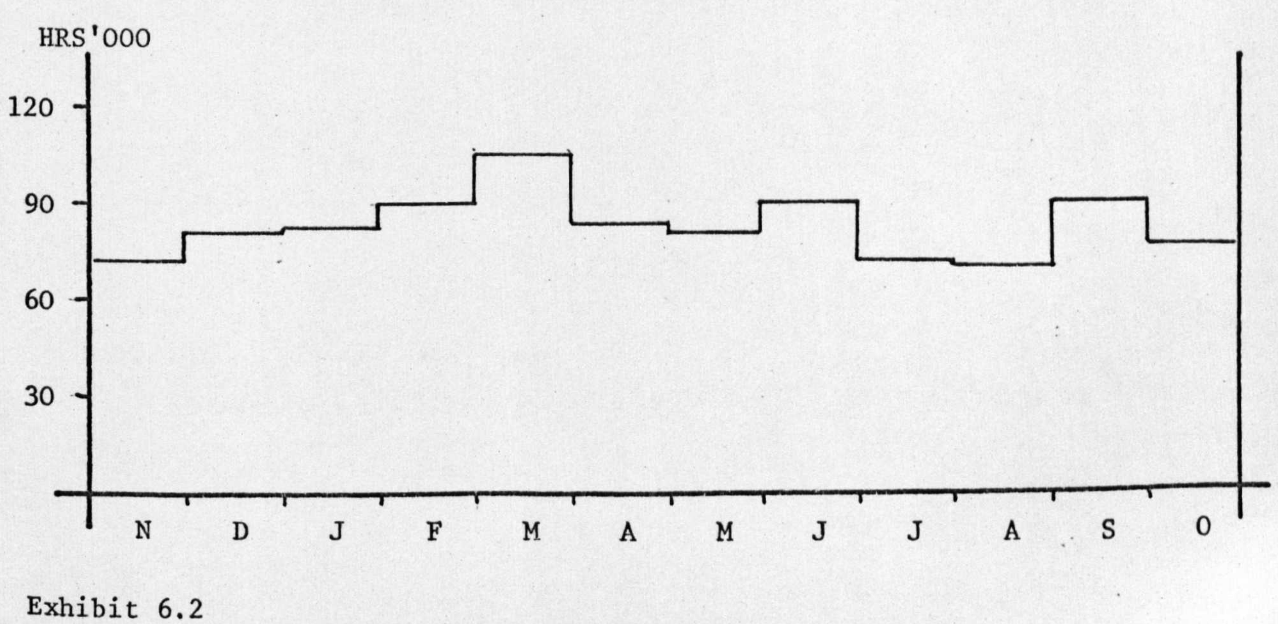


Exhibit 6.2

Some of the questions raised by the one-page summary can only be answered by reference to the full optimal solution produced by MPS/360. The relevant MPS/360 output has not been included for each of the six policy issues because the objective is to supply examples of applications not of computer listings.

2.2. Zero Initial Inventory

In the normal course of events B.D.R. would build up finished machines inventory towards the end of the fiscal year to prevent activity falling too low in a period that would otherwise be short of work and to accommodate the rapid increase in sales at the start of the fiscal year in November.

The desire to window-dress the balance sheet, on the part of the M.D., requires the very opposite of the policy dictated by considerations of profit, industrial relations and customer loyalty. In 1971, activity would be reduced by a policy of maintaining inventory levels, so that running down involves a considerabl cut-back. Then on November 1st the men are required to work full overtime, and even that will not enable production to satisfy the sales forecast.

However, ignoring the effects on the current year's operations, the corporate planners have to establish (a) the increased premiums, (b) the loss in contribution and (c) the loss in sales revenue, which will result from implementing the M.D.'s policy. They may then either be able to persuade the M.D. to reduce the severity of the plan, or suggest a sum that it would be worth paying to distributors to hold the inventory originally planned for year-end by bringing forward their purchases. The latter scheme would tend to make the current year bear the burden of rescuing the balance sheet, whereas the M.D.'s plan would benefit this year's balance sheet at the expense of next year's profits.

The only adjustment to the planning base necessary to reflect the M.D.'s policy is to set the opening inventory of each product to zero.

The results are shown in Exhibit 6.3 and compared with the planning base in Exhibit 6.4. The latter contains the planning base and the first three policy issues. Four components of the annual results are illustrated: contribution, average inventory, overtime premium and lost sales revenue. The planning base is the left-hand column of each quadrant and is distinguished by cross-hatching, except in the lower-right where its value is zero. The subsequent columns indicate the deviation of the policy variable from the corresponding value of the planning base. The purpose is to give some idea of the magnitude and the relative importance of the figures. The column immediately to the right of the planning base refers to zero initial inventory.

CONTRIBUTION: Down to 93% of the planning base of £2.299m. An absolute drop of £158,000.

F.M.I.: Down to 73% of the planning base. A saving in holding costs of £2,433.

OVT. PREMIUM: The average percentage of overtime is up from 8.67% to 11.42%, and the premium correspondingly to 132%.

LOST SALES REV: Up from zero to £79,803. In all,221 drill sales are lost.

ÉCOLE DES MINES DE PARIS

MANAGEMENT POLICY:NO INITIAL INVENTORY

REPORT FOR M.D.

DATE OF . SALES FORECAST:24/05/71

PLANNING PERIOD :FROM NOV '71 TO OCT '72

. COMPUTER RUN :06/06/71

DAYS MONTH	20 NOV	22 DEC	20 JAN	20 FEB	24 MAR	19 APR	20 MAY	20 JUN	15 JUL	15 AUG	24 SEP	20 OCT	239 TOTAL
FINANCIAL SUMMARY													F'000
REVENUE	369	385	477	511	524	589	418	452	512	420	341	401	5399
COST	-206	-227	-268	-294	-348	-295	-281	-308	-239	-233	-291	-268	-3258
CONTRIBUTION	163	158	209	217	176	294	137	144	273	187	50	133	2141
F.M.I.		6			47		40	31	17		88	120	33
OVTM PREMIUM	-2793	-1793	-3193	-3755	-2651	-2448	-820	-3211	-2631	-2786		-17	F -26146
SUBCON PREMIUM													
F.M.I. HLDG		-124			-909		-619	-1550	-250		-1686	-1845	-7002
LOST SALES REV	18752		22053	38599									79803
ACTIVITY SUMMARY													HRS'000
STANDARD HOURS	72	82	85	90	104	83	81	39	58	67	90	75	986
MADE IN	72	82	85	90	104	83	81	39	58	67	90	75	986
SUBCONTRACTED													
MANPOWER (DIRECT)	174	188	202	212	217	217	217	214	213	211	208	207	207
OVERTIME - HOURS	4330	2968	5322	6012	4418	4079	1357	5351	4468	4587		28	42951
- PERCENT	15.55	9.01	16.49	17.75	10.61	12.37	3.94	15.55	17.46	18.15	.	.08	11.42
SALES SUMMARY - %													%
FWDT	10.32	19.79	27.95	29.82	25.44	42.03	31.89	29.49	40.92	39.90	42.45	44.64	32.05
DRILL	4.70	15.10	9.76	5.79	7.44	1.35	.35	7.31	9.24	7.31	5.29	.	6.19
LOADER	9.55	8.41	10.05	9.46	8.60	9.39	8.72	9.97	7.32	7.22	8.17	8.69	8.85
DIGGER	75.62	56.75	52.28	55.07	58.69	47.38	59.09	52.30	41.98	45.80	44.22	46.79	53.04

Exhibit 6.3

COMPARISONS WITH PLANNING BASE

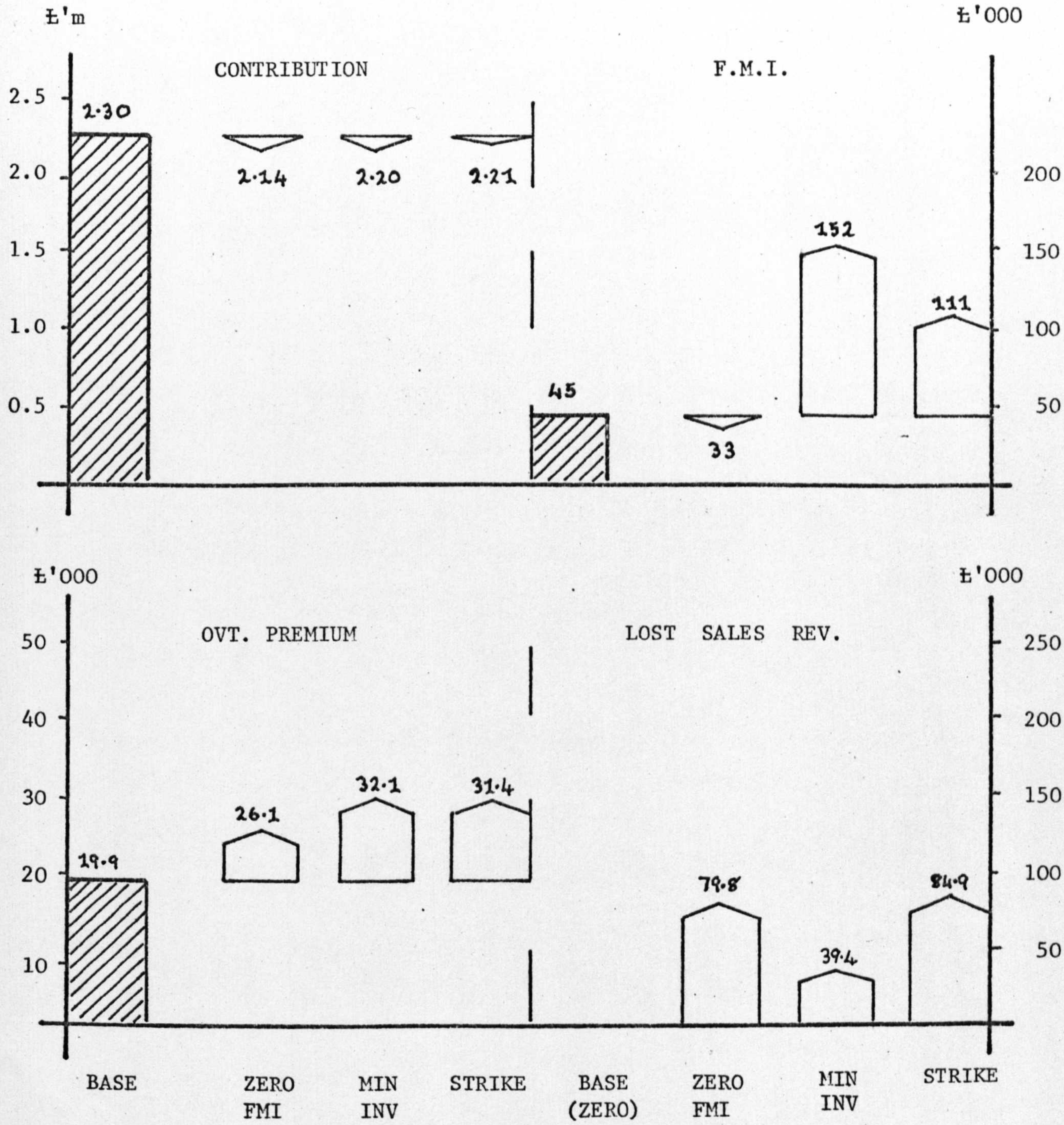


Exhibit 6.4

At first sight it may seem peculiar that losing sales worth Ł80,000 is associated with a fall in contribution of nearly twice that amount. In fact there are five main components to the reduction in cash flow during the planning period:

- Products originally scheduled to be made in the earlier period are now made in the planning period, fiscal 1972.
- A total of 221 drill sales are lost.
- Overtime premiums are up.
- Manpower is higher by 1 man in two months.
- Inventory holding costs are down.

Exhibit 6.5 quantifies each component. It is not possible to reconcile the figures completely from the M.D.'s report because of truncating errors.

The policy of window-dressing the balance sheet will reduce cash flow in fiscal 1972 by Ł158,000, and increase it in 1971 by at least Ł113,012.

The effect on the two profit and loss accounts and balance sheets depends on the accounting practices of the company over such things as charging indirect factory expenses to inventory, and so on.

However, in general, the M.D.'s scheme would tend to reduce profits in 1971 by the amount of factory overhead that would otherwise be charged to inventory. Profits for 1972 would be down by the extra premiums and the loss in sales of the drills.

LOSS OF CASH FLOW FOR POLICY OF

NO INITIAL INVENTORY

1.	Product Costs of Opening Inventory:		Ŀ	Ŀ
	.5	F.W.D.'s at Ŀ2340.12	11700.6	
	.67	Drills at Ŀ184.65	12371.6	
	.154	Loaders at Ŀ188.97	29101.4	
	.100	Diggers at Ŀ598.39	59839.0	113012.6
2.	Lost Contribution on 221 Drills			
	. 221	Drills at Ŀ176.45		38995.5
3.	Increased Overtime Premiums			6280.0
4.	Increased Manpower in August & Sept.			183.2
				158471.3
5.	Less Saving in Inventory Holding Costs			2433.0
		Loss in Contribution		156038.3

Exhibit 6.5

2.3 Minimum Inventory Policy

The marketing department used to formulate an inventory policy on the basis that the number of units of each product in inventory at the end of one month should be a fixed percentage of the following month's sales. The policy met with little approval from the factory and generated a running battle over whether there was sufficient capacity and if so whether it was desirable.

In the absence of the planning model, the problem was compounded by marketing's distrust of production control's calculations and the inability of either to quantify the cost should the policy be implemented. In fact, when the manager responsible for setting inventory levels learnt, for the first time, as a result of the planning model, that the cost in premiums, extra labour, holding costs and so on, was £300,000 per annum, he decided that the benefit/cost ratio was less than one.

The planning base establishes the inventory required for production smoothing. The minimum inventory required by marketing is expressed as lower bounds on the activity values of the inventory variables.

The effect of putting a lower limit on F.M.I. so that it is at least half the following month's sales is shown in Exhibit 6.6. and compared with the planning base in Exhibit 6.4.

The results illustrate the interactions between sales, inventory, production and rams: sales and inventory are competing for capacity; the increased demand for drills and loaders exceeds the supply of rams. In consequence, 109 drill sales are lost. Of course, it is unlikely that marketing would turn away customers while there were drills in stock.

REPORT FOR M.D.

MANAGEMENT POLICY:MARKETING MINIMUM INVENTORY

PLANNING PERIOD :FROM NOV '71 TO OCT '72

DATE OF . SALES FORECAST:24/05/71

. COMPUTER RUN :06/06/71

ÉCOLE DES MINES DE PARIS

DAYS MONTH	20 NOV	22 DEC	20 JAN	20 FEB	24 MAR	19 APR	20 MAY	20 JUN	15 JUL	15 AUG	24 SEP	20 OCT	239 TOTAL
FINANCIAL SUMMARY													F'000
REVENUE	388	385	479	531	524	589	418	432	512	420	341	401	5440
COST	-213	-262	-280	-299	-333	-290	-291	-302	-230	-218	-267	-256	-3241
CONTRIBUTION	175	123	199	232	191	299	127	150	232	202	74	145	2199
F.M.I.	117	154	156	148	178	123	171	204	130	98	161	180	152
													F
OVTM PREMIUM	-2617	-4020	-3995	-4999	-1479	-2803	-3323	-3753	-2848	-2278		-17	-32142
SUBCON PREMIUM													
F.M.I. HLDG	-1798	-2967	-2407	-2275	-3416	-1896	-2639	-3923	-2003	-1505	-3096	-2775	-30702
LOST SALES REV			19960	19400									39360
ACTIVITY SUMMARY													HRS'000
STANDARD HOURS	73	90	86	92	95	81	86	36	53	61	82	68	963
MADE IN	73	90	86	92	95	81	86	36	53	61	82	68	963
SUBCONTRACTED													
MANPOWER (DIRECT)	174	188	199	208	207	206	203	200	196	193	190	188	196
OVERTIME - HOURS	4359	6491	6376	7723	2465	4671	5524	5105	4538	3784		28	52114
- PERCENT	15.66	19.57	20.00	23.24	6.20	14.90	17.02	19.12	19.48	16.33	.	.09	14.30
SALES SUMMARY - %													%
FWDT	9.82	19.79	27.83	28.69	25.44	42.03	31.89	29.49	40.92	39.90	42.45	44.64	31.91
DRILL	9.31	15.10	10.16	9.27	7.44	1.35	.35	7.91	9.24	7.31	5.29	.	6.89
LOADER	9.08	8.41	10.01	9.11	8.60	9.39	8.72	9.97	7.92	7.22	8.17	8.69	8.77
DIGGER	71.92	56.75	52.06	53.00	58.69	47.38	59.09	52.30	41.98	45.30	44.22	46.79	52.54

Exhibit 6.6

The analysis brings home two facts that it might otherwise be difficult to establish. First, marketing's policy for sales and inventory are mutually exclusive. Secondly, even if marketing sells drills instead of storing them, costs will be up by about Ŀ33,000 (increases in-holding costs + overtime premium). As it stands, the main differences between the inventory policy and the planning base are:

CONTRIBUTION: Down to 96% of planning base by a drop of Ŀ100,000.

F.M.I.: Up to 338%, with a corresponding increase in holding costs of 325%.

OVT. PREMIUM: The incidence of overtime is up from 8.7% to 14.3% as the hours increase to 158%. The premium itself shows a bigger increase of 162%, as more expensive tranches of capacity are used.

LOST SALES REV: A total of 109 drill sales are lost, reducing revenue by about Ŀ39,000.

Perhaps one of the unexpected outcomes is that peak and average manpower are down. I wonder whether either marketing or production control would have anticipated that an inventory policy could involve more overtime and less men. The explanation is:

- The model is not allowed to run down opening inventory, which in the planning base keeps overtime low in the first three months.
- Apart from being expensive to recruit, having men underemployed is also expensive, and the rate of attrition is low. Therefore, the tendency is to hold down peak manpower.

- Effective manpower (men + overtime) is, in fact, higher for the minimum inventory situation than the planning base in the months up to and including February.
- Having higher inventories than required for smoothing may be expensive, but the result is to further smooth the fluctuations in activity. The inventories anticipate sales, forcing the model to take more preparatory action than would otherwise be the case. Further smoothing would be achieved by raising the inventory level above one-half, or requiring it to precede sales by two months rather than one.

Finally, despite higher activity at the beginning of the year, no subcontracting is called for because of the shortage of rams. If the delivery of rams was increased a certain amount of subcontracting might be needed. This could be checked by rerunning the model with the new delivery schedule.

2.4. Factory Shutdown

The timing and duration of a strike are probably easier to predict when wages contracts run for a fixed period of several years than when there is a less formal understanding to review wages annually.

The model can be used before and after the event. In the latter case the purpose is to replan the allocation of resources once a strike has occurred - an example of an operational event generating the need for tactical planning. In the former, the model would be used to determine the sensitivity of the plans to an anticipated strike, leading to modification of the original plans or the preparation of contingency plans.

Suppose that the industrial relations department forecasts a strike which sill shut the factory for March. The simplest method of building the strike into the model is to set production in March to zero by using the bounded variable technique. Ideally the manpower variables or their cost coefficients should also be set to zero as a majority of the costs associated with labour will not be incurred while the men are on strike. Of the two, it is not a good idea to set only the manpower variables to zero as this would cause the equations limiting the rate of change of manpower to make the solution infeasible. To prevent infeasibility by altering the matrix elements of the equations limiting the rate of change of manpower would require first the deletion and then the addition of entire columns of the L.P. matrix. On the other hand, the cost coefficients could be set to zero by parametric programming of the objective function. But the gain from adjusting the manpower variables does not seem worth the effort of either strategy.

My solution is to leave the manpower variables alone and to correct the financial summary after the solution has been obtained.

The outcome of a possible strike has been considered at some length in Appendix 5; the Roman numerals are for this previous use. The M.D.'s summary is reproduced as Exhibit 6.7, with the comparison still on Exhibit 6.4. The factory is working at maximum capacity plus subcontracting up until the strike: manpower is increased as fast as possible, full overtime is worked, and the limit of existing facilities is all but reached in April with manpower at 219. The building up of inventory to cover both the strike in March and peak sales in April involves the loss of 235 drill sales.

REPORT FOR M.D.

I MANAGEMENT POLICY:FACTORY STRIKE IN MARCH

PLANNING PERIOD :FROM NOV '71 TO OCT '72

DATE OF . SALES FORECAST:24/05/71

. COMPUTER RUN :06/06/71

ÉCOLE DES MINE
DE PARIS

	DAYS MONTH	20 NOV	22 DEC	20 JAN	20 FEB	24 MAR	19 APR	20 MAY	20 JUN	15 JUL	15 AUG	24 SEP	20 OCT	239 TOTAL
II	FINANCIAL SUMMARY													F'000
	REVENUE	388	385	478	525	485	589	418	452	512	420	341	401	5394
	COST	-212	-342	-344	-346	-21	-298	-283	-305	-239	-232	-289	-269	-3180
	CONTRIBUTION	176	43	134	179	464	291	135	147	273	188	52	132	2214
	F.M.I.	113	226	283	317	47	1	44	32	18		86	119	111
														F
	OVTM PREMIUM	-4246	-5088	-4981	-5242		-2666	-1064	-2772	-2631	-2647		-9	-31396
	SUBCON PREMIUM	-1815	-4195	-7116	-4979									-18106
	F.M.I. HLDG	-1742	-4335	-4371	-4895	-894	-19	-672	-1533	-274		-1663	-1828	-22276
	LOST SALES REV			20901	24959	38999								84858
III	ACTIVITY SUMMARY													HRS'000
	STANDARD HOURS	80	98	100	102		84	82	38	68	67	89	75	933
	MADE IN	78	93	92	96		84	82	38	68	67	89	75	912
	SUBCONTRACTED	2	5	8	6									21
	MANPOWER (DIRECT)	174	188	204	215	211	219	218	214	213	210	207	207	207
	OVERTIME - HOURS	6542	7840	7676	8079		4354	1773	4620	4468	4411		15	49778
	- PERCENT	23.50	23.64	23.50	23.50	.	13.10	5.09	13.48	17.50	17.50	.	.05	13.40
IV	SALES SUMMARY - %													%
	FWDT	9.82	19.79	27.69	29.02	27.49	42.03	31.89	29.49	40.92	39.90	42.45	44.64	32.11
	DRILL	9.31	15.10	9.98	8.31	.	1.35	.35	7.31	9.24	7.31	5.29	.	6.18
	LOADER	9.08	8.41	10.03	9.21	9.29	9.39	8.72	9.37	7.92	7.22	8.17	8.69	8.84
	DIGGER	71.92	56.75	52.17	53.60	63.41	47.38	59.09	52.30	41.98	45.80	44.22	46.79	52.99

Exhibit 6.7

CONTRIBUTION: Down to 96% by a drop in contribution of £85,000.

F.M.I.: Up to 257%, due entirely to the need to increase stocks of finished products in the first four months.

OVT. PREMIUM: Up to 158% of the planning base, with the percentage of overtime up from 8.7% to 13.4%. However, the average masks the fact that Sunday overtime is fully used until the strike.

LOST SALES REV.: Approximately £85,000 in lost sales revenue is caused by the cumulative supply of rams being insufficient to produce both drills and loaders. The cumulative shortfall occurs in February. The model gives priority in all months to the loader because of its greater contribution to fixed costs and profits. The method of allocating the remaining rams to drills is to backward schedule from capacity, i.e. starting with February to lose as few sales as possible in each preceding month.

If management decides not to anticipate the strike but to reschedule production and sales if and when it occurs, there is the risk of losing all the sales in March (£0.485m) and some in April because F.M.I. in February is zero. It would be interesting to combine the two policies of strike and minimum inventory. Possibly it would be a reasonable compromise between excessive premiums (from anticipating the strike) and undue vulnerability (from not anticipating it). Unfortunately, because of the expense of computer runs, it was impossible to explore combinations of policies.

2.5. A Sales Promotion Scheme

The marketing department wishes to increase the company's market share of seeding equipment by selling drills in the off-seasons. There are several months where sales and production are low and it is thought that an inexpensive promotional scheme will achieve marketing's objective as well as stabilise production rates.

One of the advantages of a maximisation model is its ability to determine whether the marginal revenue of a proposal to, say, increase sales, exceeds marginal cost. Without the model there was no general method, at M-F, for doing the calculations. There are two aspects of a promotional scheme which are of interest in the present example. The first is, should the course of action be pursued at all?. The second is, when should it be stopped?.

The ability to answer these questions could well influence the manner in which marketing formulate and implement their sales promotion schemes. For instance, a promotional scheme may be undesirable because there is insufficient capacity or because the promotional expenditure plus the premiums exceed marginal revenue. Alternatively, there may be the opportunity for more profit provided extra sales are won selectively. In the latter case, a bonus incentive scheme for salesmen, which could be quickly stoppped or only applied to the first so many units, would be preferable to full-page inserts in the national press. The questions of capacity and profitability, neither of which can be resolved by marketing alone (to base calculations on direct variable profit would clearly be wrong), make it important that marketing liaise closely with the production people before deciding on their plans for advertising and sales promotion.

Since the model maximises profits by dropping unprofitable sales, there are two approaches. One is to increase substantially the sales forecast for the drill throughout the year and allow the model to choose those which are profitable. The other is to increase the forecast only in those months when few drills are sold. In both cases it would be necessary to prevent substitution of drills for other products by fixing the activity values of the sales variables at their previous levels.

The output of the model quickly informs management how many more units can be sold, in which months and how much can be paid per unit to secure the extra sales.

Exhibit 6.8 shows the report and 6.9 the comparison. For once marketing appears to have a good idea! Selling more drills evens out the overall workload so that after the first two months it fluctuates between 3.8 and 4.5 thousand standard hours per day; the average for the year is 4.0. Average manpower is higher because now there is no need to allow it to fall away at the end of the year, with the expense of building it up again at the beginning of the next. Although total standard hours are up by eleven thousand, this is achieved without adverse movement in any of the other indices of activity.

CONTRIBUTION: Up to 102% of the planning base. An increase of £36,000.

F.M.I.: Down to 91% of the planning base, with a saving of £883 in holding costs.

REPORT FOR M.D.

MANAGEMENT POLICY:PROMOTIONAL SCHEME FOR DRILLS

PLANNING PERIOD :FROM NOV '71 TO OCT '72

DATE OF . SALES FORECAST:24/05/71

. COMPUTER RUN :06/06/71

DAYS / MONTH	20 NOV	22 DEC	20 JAN	20 FEB	24 MAR	19 APR	20 MAY	20 JUN	15 JUL	15 AUG	24 SEP	20 OCT	239 TOTAL
FINANCIAL SUMMARY													F'000
REVENUE	388	385	499	544	524	602	452	452	477	422	359	437	5541
COST	-160	-215	-247	-293	-353	-298	-284	-306	-237	-234	-298	-281	-3206
CONTRIBUTION	228	170	252	251	171	304	168	146	240	188	61	156	2335
F.M.I.	65	58	19		51		24	53	17		85	108	41
													F
OVTM PREMIUM			-1026	-3446	-2984	-2818	-1275	-2563	-1978	-2695		-915	-19702
SUBCON PREMIUM													
F.M.I. HLDG	-996	-1127	-300		-986		-368	-1219	-258		-1630	-1669	-8552
LOST SALES REV				6500		15974			34697	3494			60665
ACTIVITY SUMMARY													HRS'000
STANDARD HOURS	63	75	78	90	106	85	84	38	56	68	92	81	976
MADE IN	63	75	78	90	106	85	84	38	66	58	92	81	976
SUBCONTRACTED													
MANPOWER (DIRECT)	174	188	203	214	219	219	219	217	217	214	214	214	210
OVERTIME - HOURS			1710	5744	4974	4697	2126	4272	3297	4492		1525	32836
- PERCENT	.	.	5.26	16.79	11.82	14.09	6.06	12.29	12.56	17.46	.	4.45	8.41
SALES SUMMARY - %													%
FWDT	9.82	19.79	26.72	28.01	25.44	41.13	29.49	29.49	43.92	39.71	40.32	40.97	31.23
DRILL	9.31	15.10	13.75	11.42	7.44	3.34	7.99	7.31	2.64	7.73	10.06	8.26	8.75
LOADER	9.08	8.41	9.61	8.89	8.60	9.19	8.07	9.97	8.50	7.19	7.76	7.97	8.60
DIGGER	71.92	56.75	49.97	51.73	58.69	46.35	54.64	52.30	45.06	45.58	42.01	42.93	51.54

Exhibit 6.8

COMPARISONS WITH PLANNING BASE

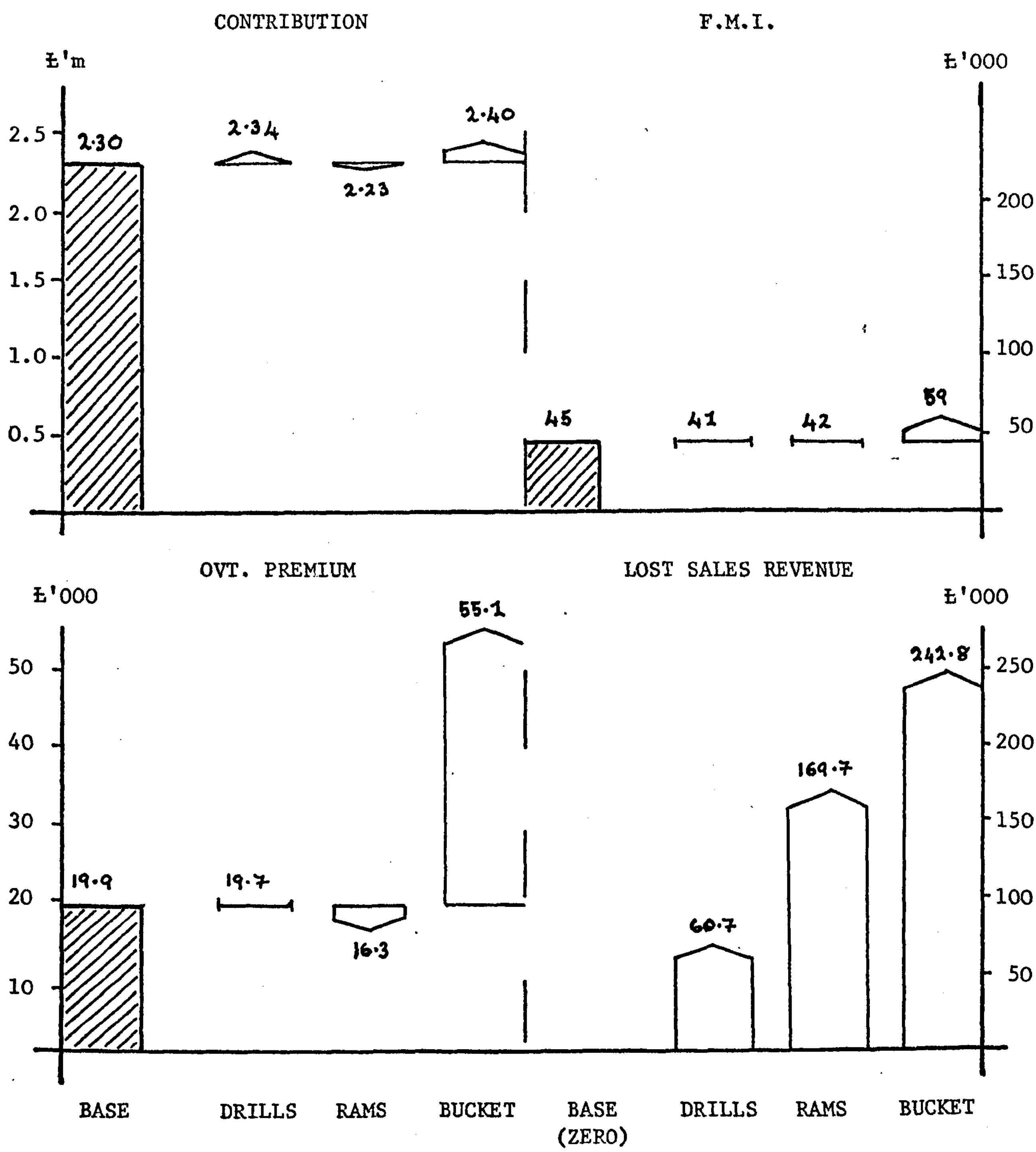


Exhibit 6.9

OVT. PREMIUM: Virtually unchanged, with a drop of Ŀ164.

LOST SALES REV.: The figures for lost sales are completely misleading. In fact, an extra 171 drills have been sold. Lost sales show up because the model was given excessive potential sales from which to choose. Whereas in the planning base there was a stock of 171 rams at year end, the present scheme uses them all.

In the process of selling more drills and rescheduling their production, the production schedule of the loader is changed (sales are unaltered). Marketing's scheme achieves several purposes: activity is smoothed, contribution is increased, more drills are sold and the supply of rams used up. Marketing should employ a selective method for generating the increased sales because both the timing and quantity are important. The present forecast supply of rams is only sufficient for additional sales of 171 units. To procure this number of extra customers it would be worth paying nearly Ŀ200 per machine if there were no incremental costs other than those included in the model.

The example illustrates the importance of a method of coordinating the plans of marketing and production control. In this case the coordination would identify the months, quantities, increased contribution and vulnerability (from a drop in the supply of rams) of a scheme to promote drills.

2.6. A Supplier Problem

The inability of a supplier to deliver material at the rate necessary to sustain production raises a number of issues. One is, how much is it worth foregoing in discounts for bulk purchases, by splitting the order between two or more suppliers?. Another is, how should the inadequatedeliveries be allocated to the products competing for supplies in order to maximise profits? Incidentally, this last question is difficult to answer with a cost-minimisation model. A third is the question specifically dealt with in this section, namely, how sensitive is the plan to a reduction of 15% in the deliveryschedule?

This problem could be tackled by parametric programming of the R.H.S., whereby a change vector is defined, and a series of solutions obtained, corresponding to successive changes of 5% in the original forecast.

An alternative approach, the one adopted, is to modify the elements of the R.H.S. vector which represent the supply of rams.

The results are in Exhibit 6.10 and the summary in 6.9. In all, 470 drill sales are lost. The resulting drop in workload reduces both peak and average manpower as well as overtime. F.M.I. is the only variable to be unaffected.

CONTRIBUTION: Down to 97%, with a drop of £66,000.

F.M.I.: Virtually unchanged.

OVT. PREMIUM: Down to 82%, a saving of about £3,500.

LOST SALES REV.: A big jump to £169,742 as 470 customers are turned away. In two months not a single drill is shipped from the factory.

There are at least four ways in which the information from the analysis could be used. Firstly, as a motive to seek out an additional source of supply. Secondly, as a guide to manpower planning. Thirdly,

Exhibit 6.10

REPORT FOR M.D.

MANAGEMENT POLICY:SUPPLIER DELIVERY SHORTFALL BY 15%

PLANNING PERIOD :FROM NOV '71 TO OCT '72

DATE OF . SALES FORECAST:24/05/71

. COMPUTER RUN :06/06/71

ÉCOLE DES MINES DE PARIS

DAYS MONTH	20 NOV	22 DEC	20 JAN	20 FEB	24 MAR	19 APR	20 MAY	20 JUN	15 JUL	15 AUG	24 SEP	20 OCT	239 TOTAL
FINANCIAL SUMMARY													F'000
REVENUE	388	385	482	493	499	581	418	450	464	407	341	401	5309
COST	-166	-206	-232	-269	-336	-288	-270	-298	-228	-225	-286	-272	-3076
CONTRIBUTION	222	179	250	224	163	293	148	152	236	132	55	129	2233
F.M.I.	71	57	13		50		30	64	17		83	119	42
													F
OVTM PREMIUM			-706	-2190	-2063	-2543	-461	-3034	-1891	-2461		-988	-16336
SUBCON PREMIUM													
F.M.I. HLDG	-1092	-1102	-203		-952		-465	-1228	-258		-1604	-1833	-8735
LOST SALES REV			16972	57054	25040	7944		2136	47304	13292			169742
ACTIVITY SUMMARY													HRS'000
STANDARD HOURS	63	69	70	78	96	79	75	84	61	52	85	75	897
MADE IN	63	69	70	78	96	79	75	84	61	52	85	75	897
SUBCONTRACTED													
MANPOWER (DIRECT)	174	174	186	195	204	204	204	201	200	197	197	197	194
OVERTIME - HOURS			1176	3651	3438	4239	768	5056	3151	4101		1647	27227
- PERCENT	.	.	3.96	11.68	8.79	13.68	2.36	15.75	13.15	17.33	.	5.22	7.66
SALES SUMMARY - %													%
FWDT	9.82	19.79	27.66	30.90	26.72	42.61	31.89	29.63	45.15	41.18	42.45	44.64	32.70
DRILL	9.31	15.10	10.71	2.34	2.80	.	.35	7.47	.	4.28	5.29	.	4.80
LOADER	9.08	8.41	9.95	9.81	9.03	9.52	8.72	10.02	8.74	7.45	8.17	8.69	8.97
DIGGER	71.92	56.75	51.73	57.08	61.63	48.03	59.09	53.04	46.32	47.26	44.22	46.79	53.65

to warn marketing not to promote drills. Fourthly, to advise the marketing and public relations departments of the need to appease disappointed customers.

2.7. A New Product

The example illustrating the role the Tactical Planning Model plays in product line decisions has been kept until last as it is the most complex and substantial.

The background to the sotry is that a hypothetical new product, the 40-7 Bucket, is planned for introduction at B.D.R. during the coming fiscal year. The analyses assume that there is enough spare general capacity at the plant to make both the bucket and the increased sales of an existing product, the digger, which will result from its introduction. This assumption on capacity has been questioned. On the outcome hang a number of issues.

Before looking at the example in detail, I want to make some comments about the relationship between strategic and tactical planning in the context of M-F, and then discuss the validity of marginal analyses in general and M-F's new product analyses in particular.

Product line decisions are often regarded as strategic and this influences the information considered necessary for analysis. This was the case at M-F, where there were five stages in the process of introducing a new product, and for each stage an analysis and, except the last stage, a decision. The first two analyses were based on little more than 'back-of-the-envelope' estimates of costs, volumes, sales price and investment;

the other three, although on firmer estimates and more detailed, retained the same scope of analysis and description of variables. The argument that this was quite sufficient to identify the two extremes, the non-starter and the jackpot, may be true, but in the agricultural machinery business most products occupy the middle ground.

It is theoretically possible that a new product could be acceptable strategically and unacceptable on the basis of a tactical analysis. Two pieces of evidence indicated that something was wrong with M-F's old system of strategic marginal analysis. The first was that the profitability of projects tended to deteriorate as the estimates were improved with each successive analysis. Secondly, even the final promise of profits seldom materialised. In part this was caused by shortfall in sales volume, but also by cost and investment overrun.

It would be possible to accept a project strategically and reject it tactically because of the different time units, variables and relationships involved in the two approaches. For example, with M-F's new product procedure, 'where will the product be made?' came late in the evaluation process; 'what other products will be made at the same plant?' probably not at all, and 'what are the sales patterns of all the products at the plant?', not until the new product had been introduced. In fact, if properly used, strategic and tactical planning are complementary. The results of tactical projections should be weighed against strategic objectives, and strategic plans should be checked for tactical consequences.

A marginal or impact analysis is based on the primary assumption that it is possible to estimate the significant changes in the values of existing variables which result from a new course of action. My suggestion is that, apart from the special case where a project constitutes a (nearly) self-contained subsystem, this assumption is usually false. In the first place, it is difficult to identify the important variables without building a model of some description. Secondly, the precise nature of the relationships between the variables probably comes to light after the model has been used on several occasions. Typically, first time through, some relationships are omitted, some of the coefficients are incorrect and so on. For example, a few of the errors in M-F's new product analyses were: direct variable costs were not appropriate for either tactical or strategic planning, the coefficients describing the products should have been standard hours per department, the labour costs generated by a product are not independent of the sourcing decision, etc.

The Tactical Planning Model makes it possible to approach the problem of isolating the effects of a particular action programme through a global analysis: the marginal analysis is obtained by differencing global analyses.

The new product analysis M-F might have produced for the 40-7 Bucket is shown as Exhibit 6.11. This is the summary which goes to the New Product Development Committee and does not, of course, include the detailed working papers. The more obvious relationships are easily verified. It is not necessary, for the present example, to explain how all the figures are calculated. The points of interest are:

- This is the third analysis, Stage 3, the one immediately prior to the commitment of funds to fixed investment.
- Period costs are all non-directly variable costs. The factory overhead, in this instance, does not include any

Exhibit 6.11

NEW PRODUCT PROFIT AND INVESTMENT SUMMARY

PRODUCT : 40-7 BUCKET ATTACHMENT
STAGE : 3
DATE : JANUARY 1971

I.R.R. : APPROX. 23%
PRODUCT LIFE : 5 YEARS
MANUFACTURING CUT-IN : FEBRUARY 1972

SUMMARY SALES, PROFIT AND CASH FLOW

	1971	1972	1973	1974	1975	1976	1977	TOTAL
UNIT SALES VOLUME	XXXX	5735	10036	11470	8602	5241	XXXX	41084
OPERATING PROFIT (£'000)								
Total Company Net Return	XXXX	540	945	1081	810	494	XXXX	1870
Less Direct Variable Cost	XXXX	178	661	756	567	345	XXXX	2707
DIRECT VARIABLE PROFIT	XXXX	162	284	325	243	149	XXXX	1163
[x] Less Impact on Period Costs	XXXX	90	115	115	115	115	XXXX	550
PROFIT BEFORE TAX & IMPACTS	XXXX	72	169	220	128	34	XXXX	613
Impact on DIGGER	XXXX	20	30	31	28	23	XXXX	132
NEW PRODUCT CONTRIBUTION	XXXX	92	199	241	156	57	XXXX	745
Less Expensed Investment	194	3	3	3	3	3		209
	(194)	89	196	238	163	54		536
Tax Adjustments		78	(30)	(72)	(89)	(54)	(14)	
OPERATING CASH FLOW	(194)	167	166	166	64	-	(14)	
Inventories, Payables, etc.		(122)	(92)	(31)	61	72	112	
Fixed Assets	(73)							
NET FUNDS FLOW	(267)	45	74	135	125	72	98	
CUM. FUNDS FLOW	(267)	(222)	(148)	(13)	112	184	282	

[x] Mainly Warranty and Policy and Factory Overhead

.../...

INVESTMENT

Ŀ'000

	SPENT OR COMMITED	TO BE COMMITED	TOTAL
A. FIXED ASSETS			
. Production Tooling		50	50
. Equipment - General			
- Special		23	23
		73	73
B. OTHER INVESTMENT			
. Development - Design	100	44	144
. Maintenance - Design		15	15
. Marketing Introduction		30	30
. Manufacturing Preproduction		9	9
. Prototype		11	11
. Other			
	100	109	209

UNIT PRICE, COST AND PROFIT

	BUCKET Ŀ	DIGGER Ŀ
Company Net Return	94.10	1198.00
Less D.V.C. - Material	36.85	560.10
Labour	9.15	40.40
Other	6.40	28.30
Packing	3.55	6.30
Freight	10.00	10.60
Direct Variable Profit	28.15	552.30
% D.V.P. to C.N.R.	30.0%	46.1%

DEPARTMENTAL STANDARD HOURS

	PRIMARY	SECONDARY	ASSEMBLY	TOTAL
Bucket	7.42	33.69	10.86	51.97

Exhibit 6.11 cont.

costs associated with direct labour. The colloquial expression for the manner of estimating these costs is that they have been 'eyeballed'.

- Impact on digger - the introduction of the 40-7 Bucket will have a favourable impact on the sales of the digger, an existing product. The effect is estimated as a 2% increase in sales volume per annum. Reference to the sales forecast in Appendix 7 on data collection will show this line to be the result of multiplying 2% of the sales forecast per annum, from the introduction of the bucket, by the direct variable profit of the digger.
- Fixed Assets (Investment section) - the investment in general purpose equipment is nil.
- Other investment - this is expensed.

As mentioned at the beginning of this section, the assumption about spare capacity on general purpose equipment has been questioned. This assumption has influenced three estimates: (a) the investment in general purpose equipment, (b) the period costs, and (c) the impact on the digger.

It is not possible to check the validity of the assumption or to generate the correct figures on the basis of either a marginal or a strategic analysis. The reasons are:

- The choice of time unit, 1 year, masks the capacity problems of seasonal sales.
- Direct variable cost, the only coefficient associated with products apart from C.N.R., is not capable of reflecting

the demand for any resource other than money.

- The marginal approach has precluded analysis of the interactions between products as they compete for resources.
- Capacity available in the separate departments should have been specifically included in the analysis.

In other words, the issues associated with the question of capacity can only be resolved by a medium-term global analysis.

The 40-7 Bucket is easily fitted into the Tactical Planning Model: its opening inventory is zero, the departmental standard hours are known, sales begin in February. The results are compared with the planning base to see the effects of providing capacity for both the bucket and the extra digger sales.

Exhibits 6.9 and 6.12 give the main results: there is not sufficient capacity (the welding department is the worst offender), marginal cost exceeds marginal revenue if two departments are working Sunday and the third is subcontracting work.

CONTRIBUTION: Up to 104% by Ŀ94,000.

F.M.I.: Up to 131%.

OVT. PREMIUM: Up to 277% of the planning base as the average percent goes from 8.7% to 21.4%. In only 3 months does the percentage fall below 20%.

LOST SALES REV: About half the potential bucket sales are lost. The reduction in revenue is just short of Ŀ0.25m.

Both standard hours and manpower are higher than the planning base. In fact the 1,094,000 standard hours produced by the factory

REPORT FOR M.D.

MANAGEMENT POLICY:MAKE BUCKET

PLANNING PERIOD :FROM NOV '71 TO OCT '72

DATE OF . SALES FORECAST:24/05/71

. COMPUTER RUN :06/06/71

DAYS MONTH	20 NOV	22 DEC	20 JAN	20 FEB	24 MAR	19 APR	20 MAY	20 JUN	15 JUL	15 AUG	24 SEP	20 OCT	239 TOTAL
FINANCIAL SUMMARY													F'000
REVENUE	388	385	499	590	572	617	451	469	517	431	399	442	5760
COST	-199	-267	-288	-225	-361	-314	-299	-317	-253	-241	-280	-318	-3362
CONTRIBUTION	189	118	211	365	211	303	152	152	264	190	119	124	2398
F.M.I.	102	144	142	22	50		33	72	17		36	89	59
													F
OVTM PREMIUM	-3748	-4932	-4854	-4824	-5608	-4212	-4450	-4955	-3909	-3895	-4785	-4931	-55112
SUBCON PREMIUM				-754		-4287	-2111		-825	-39	-138	-637	-8790
F.M.I. HLDG	-1578	-2775	-2194	-341	-969		-510	-1376	-258		-685	-1378	-12064
LOST SALES REV						29131	30654	53774	61729	50659		16876	242833

DAYS MONTH	20 NOV	22 DEC	20 JAN	20 FEB	24 MAR	19 APR	20 MAY	20 JUN	15 JUL	15 AUG	24 SEP	20 OCT	239 TOTAL
ACTIVITY SUMMARY													HRS'000
STANDARD HOURS	76	92	91	92	114	94	96	96	74	73	107	97	1102
MADE IN	76	92	91	92	114	89	94	96	73	73	107	97	1094
SUBCONTRACTED						5	2		1				8
MANPOWER (DIRECT)	174	188	204	215	220	220	220	220	220	220	220	220	212
OVERTIME - HOURS	5914	7642	7516	7551	8768	6541	6911	7763	6031	6014	7343	7713	85704
- PERCENT	21.24	23.04	23.01	21.96	20.76	19.56	19.63	22.05	22.84	22.78	17.47	21.91	21.36

DAYS MONTH	20 NOV	22 DEC	20 JAN	20 FEB	24 MAR	19 APR	20 MAY	20 JUN	15 JUL	15 AUG	24 SEP	20 OCT	239 TOTAL
SALES SUMMARY - %													%
FWDT	9.82	19.79	26.72	25.82	23.31	40.13	29.56	28.43	40.52	38.89	36.28	40.50	29.98
DRILL	9.31	15.10	13.75	11.63	6.82	1.29	.32	7.52	9.15	7.12	4.53	.	7.22
LOADER	9.08	8.41	9.61	8.19	7.88	8.97	8.09	9.61	7.85	7.04	6.98	7.88	8.30
DIGGER	71.92	56.75	49.97	48.50	54.80	46.19	55.82	51.30	42.49	45.46	38.69	43.25	50.48
BUCKET	.	.	.	6.02	7.35	3.50	6.42	2.51	.	1.73	13.70	8.38	4.14

Exhibit 6.12

represent the maximum in-house capacity starting from an initial manpower of 174. From March all departments are at the limit of existing facilities.

The model confirms that some of the assumptions of the new product analysis are incorrect. One possible reaction is that the same conclusion could be reached without the model, by a simple calculation of the supply and uses of capacity. In this particular, unsubtle instance, that is obviously true. But typically the case is not so clear cut and working out a production and manpower schedule is required. Morevoer, the schedule must be recalculated for each combination of products that could be sourced from B.D.R., and for each combination the sensitivity of the schedule to uncertainty in the sales forecasts must be worked out. I suspect that one of the reasons why the calculation was not done at M-F during the evaluation phase of new product introductions, was the difficulty of doing it once (scheduling took over one man/month); another perhaps was a lack of awareness of how sensitive the results could be to some of the factors omitted from the analysis.

Returning to the three estimates which are in most doubt: (a) more general capacity is needed in all departments, (b) the period costs omit entirely what could be substantial premiums, depending on (a), and (c) the impact on the digger should not have been calculated in terms of direct variable profit.

3. USING THE MODEL

This section briefly considers three topics which are worth a mention. The first because there is often confusion over it; the second because there is often conflict; the last because an earlier reference obliges me.

Respectively, they: distinguish the L.P. from deterministic simulation; suggest that the corporate planners are responsible for building, running and maintaining the model; show how the model could be part of a more traditional planning system such as I.P.C.

3.1. The Model

The model can be used in two entirely different modes: the discretionary and the non-discretionary. In the latter, the model's room for manoeuvre is limited by the parameters of the policy issues management wishes to evaluate. In the former, the model is given as much freedom as possible: in practical terms this means that the only limits on the activity values of variables are the two facilities restrictions, on the capacity of general and special purpose equipment, and the figures for opening manpower and opening and closing inventory.

Optimising the model with these minimum restrictions establishes the planning base: the 'do-nothing' situation of Integrated Planning and Control (I.P.C.). Changes to the planning base are the result of new management action. Whether the new action is promotional expenditure to increase sales or investment to reduce costs, etc. the proposed new actions are evaluated and the new plans derived by putting the changes into the model, rerunning and so obtaining a new global picture. The effects of the new action are the differences between the new results and the planning base. In other words, marginal analyses are the result of differencing global analyses. This is in contrast to the approach which attempts to produce marginal analyses directly by estimating only the changes in the values of the decision variables caused by the new action. In fact, marginal analyses will frequently be based, not on the relationships between variables, but on estimates of their consequences. The example in this appendix on the new product illustrated some of the inadequacies of the direct marginal analysis.

To recapitulate: the first step is to establish the planning base; the second is to evaluate proposed new management action by comparing the results of running the model under the new assumptions with the planning base.

Each policy issue, except the 40-7 Bucket, involved reducing the boundaries of the feasible region. The advocates of deterministic simulation might say that the effect was to so restrict the degree of freedom that the model was little more than a budget compiler. If this was true it would be difficult to justify the expense of an L.P. programme. In the event, the feasible region, having been reduced by including the policy issue, is still large. Anyone in doubt should attempt to check out the optimal solution. Sometimes it is difficult to trace why the model has adopted an unexpected allocation of resources.

3.2. The Corporate Planning Department

One role of the corporate planning department is to adapt the basic model to accommodate proposed new action. To realise the full potential of the model requires a knowledge of its construction and of the working of L.P. It is possible for the corporate planning department to view the model as a black box, maintained and run by the M.I.S. department. I am not aware of any general arguments in favour of the latter approach. The effect tends to be either that the model is used only for a few well-defined and frequently recurring situations or that its versatility is retained and at least one other interface is added to impede the flow of information between top management and the model. In both cases the results seem inferior to the alternative of combining the skills and knowledge in a single department.

The basic model, as I have described it, contains the variables which, in the normal course of events, represent the main components of the resource allocation process. However, there will be a continual stream of new planning situations: at one time cash flow will be important; at another buying out of the piece-rate system; at a third setting up a new assembly plant; at a fourth minimising fluctuations in production (see Gass); all these can be accommodated by modifying the basic model. But adapting the model becomes more difficult with each additional interface between the user and the model: lines of communication are lengthened, the probability of delays and errors increased.

3.3. The Planning Model and I.P.C.

Costs are frequently described as being either engineered or managed. Broadly speaking, the former correspond to direct variable costs and the latter to indirect costs.

The relationships implied by engineered costs in manufacturing industry are suitable for inclusion in a model for several reasons:

- Mostly they are linear over the whole range of variation of the relevant variables (standard hours per product per department) or can be split into piecewise linear segments (direct labour costs).
- They are more characterised by stability than instability.
- Changes to them should be 'engineered' and a formal procedure established to make sure that people know what the changes are, what they affect, what they cost and when they cut-in.

Therefore, it is possible to revise the coefficients in the planning model as significant changes occur.

Managed costs are more difficult to predict and revise. At M-F these were split out by budget centre and estimated by the man responsible. One of the problems was to supply the head of budget centres with information they felt was needed on the independent variables. Many of the independent variables were directly or indirectly part of the planning model. An example of the former is the overtime worked in the secondary department in July, and of the latter, the number of material handlers in the primary department.

The planning model can be used to provide estimates of independent variables during the formal planning cycle as well as at other times when a revised plan is to be submitted.

The model does not reduce the discretion of management to manage indirect costs. Rather, the two systems are complementary in that the model provides better estimates on which the other plans can be built.

The responsibility, project and time-period accounting of I.P.C. should benefit from the improved handling of the relationships between the dependent and independent variables of engineered costs.

4. DESCRIPTION OF THE M.D.'s REPORT

This topic is considered thoroughly in Appendix 5.

The report is divided into four sections, see Exhibit 6.7: headings, financial summary, activity summary and sales summary. Each is described briefly.

I Headings

- Printed in the top left-hand corner is the name of the proposed action programme which is being analysed, and the end points of the planning horizon.
- The report only covers the first 12 months of the 13 month time horizon of the model. This is to retain compatibility with the existing internal and external planning and reporting procedures. Information on the 13th month is available from the output of the L.P. package.
- Some of the variations in the figures are due to the different number of working days each month. The numbers refer to the normal working week and do not include overtime.

II Financial Summary

- The financial summary - this is divided into two parts. The first contains the aggregation of all the financial data (activity level X input cost) into the main financial categories.

Revenue, cost and contribution are an identity: they are not lagged by the giving and receiving of credit. F.M.I. is the value of finished machines inventory at the end of the month. The second part gives details on three components of the cost line above (the purpose of the fourth - lost sales revenue - will be explained in a moment). They are the more volatile elements of the cost of production and indicate when the level or rate of change of activity are causing workload problems: their significance is that heavy premiums or a high F.M.I. holding cost can quickly erode the profitability of the marginal sale. One innovation is the possibility of reading off both the value of inventory and the holding cost caused by different policies. At M-F these tended to be discovered after the event from the size of the overdraft and the bank charges. The last item in the section - lost sales revenue - represents the value of the sales foregone, because to make the products would either have been unprofitable or impossible. There is nothing to prevent management from giving priority to part of the sales forecast, or indeed from forcing the model to meet the entire forecast. This can be achieved by setting minimum bounds on the value of the sales variables or by changing the sales restriction to an equality.

III Activity Summary

. The activity summary - the information in this section expresses the level of activity in non-financial terms. Standard hours are the units in which the capacity of the factory and the work generated by a production programme are measured. Thus people will say 'we have never had more than x million standard hours out of the factory'. The total standard hours called for by a production programme (products X standard hours per product) can be supplied by the factory or by subcontractors - the next two lines show the split. Manpower cannot be calculated directly from the production schedule. The reason being that the tendency for manpower levels to follow fluctuations in workload is modified by the costs of hiring and firing and the limits on the rates of change; with the result that the manpower in any month is a compromise between short-term fluctuations and long-term trends. Overtime percent is the ratio between the total overtime hours and the total normal attendance hours (40 hours per week per man).

IV Sales Summary

. The sales summary - the percentage breakdown by products of the monthly sales revenue. This is the optimum sales mix given the original sales forecast and the production facilities.

APPENDIX 7

DATA

COLLECTION AND CONVERSION

CONTENTS

List of Tables and Exhibits

DATA

1. INTRODUCTION

This appendix describes in detail the data required to construct the tactical planning model at the M-F plant of B.D.R. The volume of data has been kept down by reducing the number of products, departments and so forth, while retaining the complexity of the operations at B.D.R. Section 2 identifies the departments that generate the information, suggests forms suitable for data collection and discusses why the data is needed. Section 3 explains any calculations that are necessary before the data is suitable as input to the model and gives worksheets for carrying out these operations.

The justification for going into such detail is that firstly it makes it possible, together with the information on coding variables in Appendix 8 (Construction and Running), to follow the input listing in the latter appendix. Secondly, it gives a feeling for the process of data preparation to a would-be model-builder. And lastly, it makes it easier to appreciate how the model works and therefore the limitations and possible extensions.

The final section gives some definitions of terms with which the reader may be unfamiliar, or which are peculiar to M-F, or which current usage has made ambiguous.

2. DATA COLLECTION

2.1. Production Control

The task of production control in the planning process is to turn a requirement for products (basically a sales forecast plus finished machines inventory policy) into an acceptable production programme. The requirement for products is really a request for capacity. The production programme and its manpower plans represent the supply of capacity. Production control, working within the limits of existing facilities, together with changes already planned, picks out the shortfalls and excesses of capacity and thereby triggers off requests for additional productive resources. The result of production smoothing is a schedule by month showing the direct manpower in each department, the number of each type of product produced and the finished machines held in inventory for production smoothing purposes.

Thus, the two key functions of production control in the planning process are:

- to smooth production
- to identify changes in resources that would assist production smoothing.

As production smoothing is the major activity of production control, I will spend a little while considering what it is and how it affects resource allocation, before going on to the 'nuts and bolts' of production control data. The subject is also treated in Appendix 1 Section 4.

Typically, the throughput of a factory is limited by a series of bottlenecks. A production programme represents a compromise between the finished products requested by sales, and the restrictions imposed on production by the different bottlenecks. In the literature this is called 'the production smoothing problem'. For a detailed discussion, the reader ought to go to a book specialising on production. I am not concerned, for the moment, with how this compromise is reached, but rather with understanding the structure of the problem, the way it affects the allocation of resources and how to decide what data is needed to solve it.

The potential capacity of a factory is determined by these bottlenecks. The justification for talking about the machine shop, the welding department, etc. is that a group of similar operations (corresponding to an area of specialisation in equipment and labour skills) represents the major potential bottlenecks. In fact there are two forces at play that can hold up production:

. labour loading

. machine loading.

This is another way of saying that production can be limited by either not having the right men or not having the right eqipment: thus, the production smoothing problem has two components.

Doing labour loading and machine loading at the departmental level is correct if, broadly speaking, there is mobility of labour and versatility of equipment within the department, implying that it is at the departmental level that bottlenecks appear. However, where there is a lack of mobility or of versatility, bottlenecks can be generated within a department either by a particular group of machines - the radial arm drills - or by a particular class of skilled worker - the capstan lathe operators. Production smoothing then has the task of ensuring not only a smooth flow of work through the machine shop, but also through the radial arm drills, and so on for each bottleneck.

The final complication that must be mentioned is that there is a qualitative difference between labour loading and machine loading. In the latter case there are no industrial relation problems from having machines idle, so the restriction imposes only an upper limit on machine utilisation, whereas in the former, the restriction operates in both directions and the objective is to minimise fluctuations.

Before glancing at one method of tackling the production smoothing problem, the position can be summarised as follows:

> the objective of production smoothing is to minimise the fluctuations in activity of each group of workers while staying within the capacity limitations of each distinct group of machines.

The question is how to solve the problem in the light of the role production smoothing plays in the process of resource allocation.

As already mentioned, there are two components to the production smoothing problem - labour and machine loading - that can be solved either consecutively or simultaneously. The latter implies a large problem. At M-F production control produced manpower plans first and then did machine loading. The influence production smoothing had directly on the allocation of existing resources and indirectly on the allocation of new resources, was not explicitly recognised by the planning system, no perceived by the corporate planners. The result was to leave production smoothing entirely in the hands of production control. The corporate planning department accepted the factory production schedules, manpower plans, etc. without enquiring too closely about how they were derived and the assumptions behind them. Such an approach is equivalent to treating the factory as a black box: the box happened to account for most of the company's resources, however measured.

Another method is to say that the factory is far too important a recipient of company resources to be outside the influence of the corporate planners, but, on the other hand, there is no desire to take over the role of production control. One answer is for the corporate planners to construct a small model of the factory, which generates overall production plans that are acceptable to the factory and which solves the labour and machine loading problems simultaneously.

In the event, it is possible to tackle the two problems simultaneously and to keep the complexity and size down to a reasonable level. The trick is to treat the machine loading problem as a subset of labour loading. A careful choice of variables and data permits the control of the maximum capacity of the former and fluctuations in the latter.

The procedure is as follows: identify the equipment bottlenecks (radial drills, 500 ton press .....); break down the standard hours required to make each product over these equipment bottlenecks; group the equipment bottlenecks into units amongst which there is mobility of labour; treat the labour assigned to each unit as the level at which the labour loading problem operates.

This approach has a number of advantages:

. either lack of manpower or lack of equipment is able to choke off production,
. the two problems are solved simultaneously in the sense that both sets of restrictions are satisfied by the solution,
. the production smoothing problem is kept down to manageable proportions.

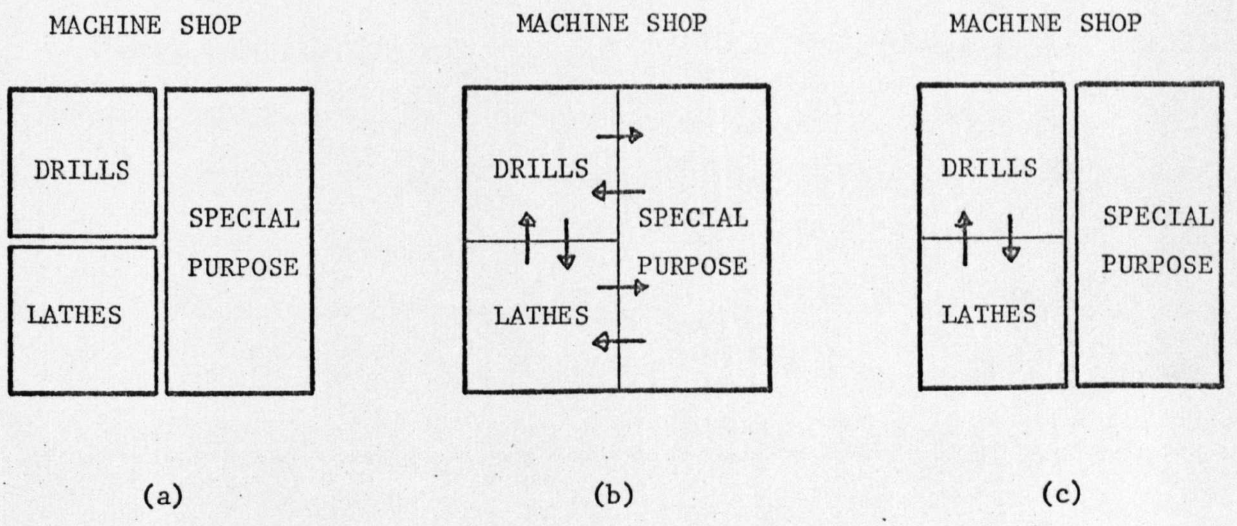
The only disadvantage is that when this information is turned into the appropriate equations, it is not possible to have a uniform system as there will be a number of variants:

- departments in which there are no individual equipment bottlenecks, and where capacity is limited by manpower
- departments which divide into two or more equipment bottlenecks in which;
  - (a) there is no mobility of labour between the equipment groups (in this case each equipment group is treated as if it were a department)
  - (b) there is mobility between all the equipment groups
  - (c) there is mobility between some of the equipment groups.

It must be emphasised that this approach only works because the equipment groups are combined into units within which there is mobility of labour. The following diagrams show the last three possibilities:

EXHIBIT 7.1

LABOUR AND MACHINE LOADING



Applying the rules; in each of the cases, (a), (b) and (c), the conventional machine shop is divided into three main 'machine groups' (bottleneck groups) whose capacity is controlled separately; in (a) the three machine groups are treated as three distinct labour units - there is no mobility of labour between machine groups; in (b) the three groups are treated as a single labour unit - there is complete mobility of labour; in (c) the drills and lathes are treated as one labour unit and the special purpose equipment as another.

To simplify the forms and subsequent discussion, I will assume that there are no machine group bottlenecks within departments, and that there is complete mobility of labour within departments, i.e. both machine groups and labour units correspond to the divisions into departments. The reader can expand the data collection procedure to accommodate any complications he comes across in practice. From mow on I cease to refer either to machine groups or labour units as distinct from the conventional productive departments.

2.1.1. Capacity Required per Product

Production planning requires the definition of a reasonably stable relationship between products and the manpower necessary to make them (their men-equivalent). The relationship has four components: standard hours, adjustment for spares and scrap, standard hour performance, and hours available per man. The schematic relationship is shown next.

PRODUCTS $\downarrow$ MEN $\uparrow$

$$\left(\underbrace{\left[\text{Standard Hours} \div \left(1 - \text{Scrap \& Spares Rate}\right)\right]}_{\substack{\text{Input Hours} \\ \left(\text{Convert from Output Hours}\right)}} \div \text{Standard Hour Performance}\right) \div \text{Hours Available per Man}$$

$$\underbrace{\left(\ldots\right)}_{\substack{\text{Clock Hours} \\ \left(\text{Convert from Standard Hours}\right)}}$$

Production control is responsible for supplying all the data involved in this equation, by which products are transformed into their men-equivalents. The next two tables show how the data could be collected.

DEPARTMENTAL STANDARD HOURS

PRODUCTS	DEPARTMENTS Primary	Secondary	Assembly	TOTAL
FWD	48.05	136.36	95.20	279.61
Drill	18.40	44.29	65.83	128.52
Loader	12.70	77.25	14.61	104.56
Digger	23.22	132.08	53.02	208.32

Table 7.1

OTHER DEPARTMENTAL INFORMATION

	Primary	Secondary	Assembly
Scrap Rate	1%	5%	1%
Spares	4%	6%	1%
Standard Hour Perf.	207%	220%	255%

Table 7.2

Now, perhaps, is the time to mention that since the model is a multiperiod model, much of the data (and especially that in the two previous tables) is replicated for each time period. This is not an assumption that lies behind the construction of the model, which might be the case if a matrix generation programme was used, but instead, reflects the inability or reluctance of most of the departments to give more accurate estimates. A good example is the standard hour performance. Clearly, the figures for this are important and could account for swings in manpower of anything up to 50%. It is known that the introduction of a new product has a considerable adverse effect on the performance figures as the build-up of new parts occurs. The accuracy of the plans would be significantly improved if it were possible to estimate both the magnitude of the initial adverse impact and the duration of the climb back to normal operating conditions.

Thus far, the data has been collected to calculate the requirement for capacity in each productive department. The next step is to derive the capacity available.

2.1.2. Capacity Available per Department

This divides into two parts: firstly, the average number of hours available per man in each period - the capacity available per man, and secondly, the maximum capacity available, which is determined by the existing capacity at the beginning of the planning period, the maximum capacity of each department with the existing equipment, and finally, the limits on the rate of change in capacity from one period to the next - upwards and downwards. Whereas in Tables 7.1 and 7.2 above the data was the same for all time periods, this is emphatically not the case for the capacity available per man.

There is no alternative but to list all the relevant factors. To help stave off boredon, I reiterate the motivation for the first part of the present section - to gather the data from which to calculate the average number of hours available per man in each period, both in normal time and for the several different rates of overtime. To avoid unnecessary repetition, it should be noted that this information is required for each period:

- the number of working days and the number of weeks (the year is split symetrically into 4 and 5 week periods)
- the number of shifts worked in each department
- the proportion of men on each shift
- the length of each shift
- the number of overtime hours each shift can work
- the number of overtime hours, or the percentage of overtime hours, that are reserved for accommodating operational problems - and therefore are exluded from the calculation of the number of hours potentially available per man.

Table 7.3 shows the data required on the number of working days and the length of the months throughout the period. The full significance of some of the entries in this table will become apparent later on. For the moment, suffice it to say that the 'month' code is necessary for the definition of variables in the L.P. programme, and this might as well be done by production control as anyone else.

Table 7.3

WORKING DAYS AND WEEKS

CODE	A	B	C	D	E	F	G	H	I	J	K	L	M
MONTH	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
WEEKS	4	5	4	4	5	4	4	5	4	4	5	4	4
DAYS	20	22	20	20	24	19	20	20	15	15	24	20	20

Table 7.7

RESTRICTION CAUSED BY A SUPPLIER

RESTRICTION DUE TO:	KESSNA HYDRAULIC RAM	
PRODUCTS AFFECTED:	DRILL	LOADER
NUMBER USED/PRODUCT:	1	1

PERIOD '72-'73	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
DELIVERY SCHEDULE	200	220	200	200	240	190	200	200	150	150	240	200	200

SHIFT AND OVERTIME INFORMATION

	Days	Nights
Percentage on Shift	60%	40%
Length of Shift	8 hours	10 hours
Days/Nights per Week	5	4
Hours/Week	40	40
Potential Overtime Hours at: 1 1/3	-	-
: 1 1/2	5	10
: 2	8	-
Reserved Overtime Hours at : 2	4	-

Table 7.4

Table 7.4 applies to all departments. Clearly, if different practices were followed in one or more departments, this information would need to be collected on a departmental basis. In fact, at the division of the company where this study was carried out, the heat treatment department (for the purpose of the illustration in my thesis, combined with the press and forge department to form the primary department), worked three eight hour shifts due to the necessity of keeping the cyanide ovens, etc. at a constant temperature. This arrangement had repercussions on the number of potential overtime hours, and so forth. One must be aware of the possibility that certain sections of the productive labour force, for one reason or another, do not work the same hours, nor are they paid in the same manner, as the others. Incidentally, because of the difficulties of setting 'allowed times' for case hardening a part, the heat treatment department was paid on a day rate, instead of the piece-rate system used for the other productive departments.

The reason for collecting data on the different rates of overtime, 1 1/3, 1 1/2 and so forth, is to permit the calculation of the cost and size of successive tranches of capacity. The tranches correspond to overtime during the week (1 1/3), overtime on Friday night and Saturday morning (1 1/2) and overtime on Sunday (2). The ratios refer to the premiums paid on the day wage (the attendance element, as opposed to the bonus or rate-of-working element) to induce people to give up their leisure time. It reflects, for instance, the notion that Sunday has a higher utility as leisure than Saturday and therefore the premium must be higher for the former than for the latter. Interestingly, this approach is at variance with the advertisement for a Sunday newspaper which had as its copy 'Don't go to pieces on Sunday, read the ....'! Perhaps the order of the premiums should be changed.

I turn now from the data on capacity available per man to that on the capacity available per department. At the start of the planning period in question, there will be a certain number of production workers in each department, thus determining the initial capacity. There are a number of approaches to this initial figure:

- it could be the inevitable result of current management policies - to increase, reduce or maintain the existing labour force
- it could be the existing labour force, with the assumption of no change
- it could be treated as a variable to be determined by a series of 'what-if' questions, and would therefore imply the labour policies to be pursued in the meantime.

Table 7.5 gives the relevant figures for the simplified model of B.D.R.

Potential capacity, as mentioned earlier, can be limited either by a shortage of men or by a shortage of equipment. This is the next issue to be resolved. For each department there is a certain number of men who can be accommodated without additional investment in facilities - called the 'maximum manpower' of a department, see Table 7.5.

Now the only missing information is the rate at which departments are able to change their level of manpower. Usually this is expressed as a rate of change from one month to the next. In the upward direction, the limit is imposed by the need to hire, train and assimilate the new recruit. In the downward direction, the limit can be set by either of two extremes - with and without redundancy. In the first case the potential rate of change is high and so is the cost. In the second, the rate, fixed by natural wastage,is low, and so is the cost. My recommendation is that for the downside,production control should be asked for information about natural wastage. Firstly because in the normal course of events redundancies should not be part of the day-to-day running of a factory, and secondly because the rate of redundancy that a company can tolerate is a general management decision. If management wishes to evaluate the consequences of such a policy, the model can be modified accordingly.

SIZE OF DEPARTMENTS AND TURNOVER

	Primary	Secondary	Assembly
Starting Manpower at 1/11/72	23	106	45
Maximum Manpower	30	135	55
Max. Rate of Increase	12%	8%	10%
Max. Rate of Decrease	0.65%	2.00%	0.45%

Table 7.5

There is a complication which has been glossed over - it is the choice between working in 'effective manpower', i.e. so many men's worth of work, or in 'men on the books', i.e. headcount. The difference is explained by non-attendance, for whatever reason: oversleeping, absenteeism, illness, etc. Production control is more interested in the figure for 'effective manpower' than headcount, so it is preferable to work with the former rather than the latter. Clearly, it is a trivial matter to convert one set of figures to the other.

The final data provided by production control concerns the limits imposed on production by 'jigs and fixtures'. These are special purpose pieces of equipment used to locate parts that are being welded together etc. Some jigs and fixtures are peculiar to an individual product, others are common to several products, but not the whole product line. The effect of these jigs and fixtures is to limit the maximum rate of production either of individual products or of groups of products.

Such equipment exists mainly in the secondary and assembly areas, and production control is asked to identify only the severest restriction for each product or group of products. The figures are given in Table 7.6.

LIMITS ON RATES OF PRODUCTION

	Maximum Daily Rate of Production
INDIVIDUAL PRODUCTS	
FWD	2.0
Drill	7.5
Loader	5.0
Digger	10.5
Bucket	3.2
GROUPS OF PRODUCTS	
Drill, Loader	10.0

Table 7.6

It would be a mistake to leave production control without mentioning the versatility of the model to cope with irregularities; for instance, from time to time there may be some unexpected restriction on production caused by the inability of a supplier to meet his delivery schedule. This restriction can easily be incorporated into the model provided it is possible to express both the supply of and the requirement for the part (raw material, etc.) in units per product. The example in Appendix 6. illustrates the effect of an inadequate delivery schedule of a hydraulic ram. The additional information required is shown in Table 7.7, page 7.14.

To summarise the reason for getting so heavily involved with production control data: the tactical plans produced by production control influence directly or indirectly the allocation of a major part of the company's resources and therefore its profitability. If corporate planning wishes to ensure that overall plans are (a) consistent and (b) optimal, then it must be possible to evaluate both the trade-offs and the vulnerabilities of different courses of action without playing a 'what-if' game at arm's length with production control: a game biased heavily in favour of the latter.

The objective is made realisable by a careful definition of the data required: both labour and machine capacity are expressed in standard hours; productive facilities are divided first into bottleneck groups (of similar machines) and then into labour units (within which there is mobility); the two loading problems are solved simultaneously.

And last of all, the provision of productive capacity is treated as a variable, and the role of resource allocation is to continue changing the supply of capacity either until a restriction is encountered, in which case one wishes to know how much it is worth paying to remove the restriction, or until the profit from an extra sale is less than the additional cost.

2.2. Finance

2.2.1. Product Costs

The cost accounting section of the finance department is responsible for maintaining a standard costing system. The standard cost of a product is set at the beginning of the year and differences between standard and actual costs are accumulated in variance accounts. The procedure for revising the standard costs is:

Last year's standard
\+ Labour variances
\+ Environmental forecasts
\+ Design and Methods changes
\+ Specification changes
= New standard cost

At first glance it should be possible to go from production control's standard hour data through to the cost section's standard cost. In practice the figures can only be reconciled at one point in the year - the time when the new standard costs are established. Only at that moment are production control and the cost section working with the same data.

From then on, production control updates its figures to reflect any significant change that occurs due to design and methods or specification. The objective is to calculate accurately the capacity required to meet a sales forecast.

Yet another source of discrepancy are changes in the productivity of the factory. This alters the relationship between

standard hours & clock hours

and therefore between

products & men

which were assumed when the standard costs were set up.

A final point before looking at the forms and the data is that the company uses a direct costing system.

The chief characteristic of a direct costing system is the division of costs into those that are directly variable and those that are not,i.e. the latter are defined by exception and are written off in the period in which they are incurred. Under this approach there is no attempt to allocate either semi-variable or fixed costs. Of course, for planning purposes management wishes to know which costs are truly fixed, in that they are part of shutdown expense, those which are to all intents and purposes fixed provided the company stays in business, and those that vary, but not directly with volume.

The advantage of a direct costing system is the identification of the marginal cost of making one more unit of production. No one would claim this to be the whole of the story, of course some other costs will be affected, but it is argued that direct costing gives a much better indication of the marginal cost than does full absorption costing.

So the cost data is generated by a standard, direct, costing system.

Table 7.8 below shows the standard cost of each product split out by main categories.

UNIT COST SUMMARY

	FWD	Drill	Loader	Digger
DIRECT VARIABLE COSTS	£	£	£	£
Material	2267.97	167.60	172.05	560.10
Labour	55.03	23.50	18.85	40.40
Labour Allowances	27.00	9.50	8.45	17.40
Processing Supplies	20.00	6.20	4.40	10.90
Packing	19.40	0.50	3.65	6.30
Freight	47.00	8.90	6.25	10.60
TOTAL D.V.C.	2436.40	216.20	213.65	645.70

Table 7.8

The cost section is able to read the data in Table 7.8 straight from the product cost sheets. Before using the information it is necessary to know what costs are included in each of the categories. The definitions are given at the end of the present appendix.

2.2.2. Labour Costs

Wrapped up with the cost of employing direct labour is the question of how they are paid. Whether or not a piece-rate system is used, it is fairly common for there to be a fallback pay to protect the men from the consequences of stoppages that are beyond their control. In addition, there are frequently overtime and night-shift premiums. The cost section should be asked for the details. Those for the B.D.R. factory are given in the following table.

PAYMENT OF DIRECT LABOUR

		Cost Category	
Method of Payment:	Piece-rate + Premiums		
Description:	Flat rate plus bonus incentive linked to rate of working plus premiums for night shift and overtime working		
Components of Wage:	Day Wage * Attendance Hours	D.V.C.	(a)
	+ National Award * Time Taken (clock)	D.V.C.	(b)
	+ Basic Wage * Time Earned (std. hrs)	D.V.C.	(c)
	+ Day Wage * Ovt.Prem. * Attendance Hrs.	Period Costs	(d)
	+ Day Wage * N.S.Prem. * Attendance Hrs.	Period Costs	(e)

Notes: Day Wage, National Award and Basic Wage are three hourly rates of pay which are negotiated to the fifth decimal place of a pound.

(a) is the flat-rate attendance

(b) and (c) the bonus

(d) the premium for overtime, and

(e) the premium for night shift.

The last two are to do with when the work is done not the rate of working.

Table 7.9

Since most systems for paying direct labour have more than one component, it is important to discover what these are and how they are calculated. For instance, at B.D.R. there were three components: a combination of being available for work, of rate of working and time of working. To ensure that the system is understood and the labour costs correctly related to the factors which generate them, the cost section should be asked for a written description of the method of paying direct labour. The next table explains the principles governing the system at B.D.R.

PRINCIPLES OF METHOD OF PAYMENT

There are three basic components that go to make up the wages of direct labour:

(a) the Day Wage

(b) the Bonus - National Award
Basic Wage

(c) the Premiums - Overtime
Night Shift

The Day Wage is a flat rate of £0.4 per attendance hour.

The Bonus is based on the actual time taken, in clock hours, and the output produced, in standard hours.

The Premiums relate to when the work is done. They are calculated as an addition to the Day Wage and are expressed in these terms, i.e. 1 1/2 stands for time and one-half (1 1/2x£.4), of which the normal Day Wage is represented by the 1, and the premium by the 1/2.

The Overtime Premium Rates are	1 1/3	- overtime during the week
	1 1/2	- Friday night & Saturday morning
	2	- Sunday
The Night Shift Premium is	1 1/3	

Table 7.10

Fortunately, one is not concerned with the intricacies of the system - just with identifying the basic elements, discovering how they are generated and where they are posted in the accounts.

While it is not possible to establish a procedure to elicit the correct answers in a wide variety of different industries, it is possible to reiterate the motive that prompts the questions. This is to identify:

- the marginal cost per product
- the marginal cost per man.

And although the direct costing system comes closer to achieving these objectives than any other system, it would be a mistake to assume either that the data was necessarily suitable for planning or that some fundamental corrections could not easily be made.

The next series of costs are all available, but probably require some digging out. They are concerned with the marginal costs of different manpower policies.

The first item is the cost of employing one man for each month of the planning period, whether or not he works. This cost is important because in the situation where sales are temporarily falling off, management wishes to evaluate the relative merits of:

- firing and rehiring
- building up inventories
- having men underemployed.

The cost of employing a man, irrespective of his output is made up of such things as:

- holiday pay
- canteen subsidy
- national health and insurance
- nightshift premium
- fall back pay.

The first three are proportional to the length of the month, the last two to the number of working days in the month. The cost section is asked for information on the costs that vary with the length of the month; those that vary with the number of days are calculated in section 3 of this appendix. The former are in Table 7.11.

FIXED LABOUR COSTS

	Length of Month	
	4 weeks	5 weeks
	£	£
Fringe Benefits	10.0	12.5
Fringe Benefits + Holiday Pay	29.9	32.4

Table 7.11

There remain four miscellaneous costs. It is unlikely that the cost section has the data immediately available, although it may be fairly easy to calculate, depending on the detail permitted by the chart of accounts, and the manner in which the entries are aggregated. In fact, this emphasises one of the major strengths of the tactical planning model; for the most part it uses data already available within the company. By reorganising some of the data and using L.P. techniques it is possible to secure a considerable improvement in the quality of corporate plans.

The significance of the following data will become more apparent at the formulation stage of the tactical planning model. The data outstanding is given in Table 7.12 overleaf.

COST OF LABOUR TURNOVER

	DEPARTMENT		
	Primary	Secondary	Assembly
	£	£	£
Cost of Increasing Manpower	35.0	35.0	110.0
Cost of Decreasing Manpower	5.0	5.0	5.0

Subcontract Premium = £0.635/standard hour
Inventory Carrying Cost = 20% of D.V.C. per annum

Note: The Costs of Increasing and Decreasing Manpower refer to the one-time costs per man. The former is made up of such items as: advertising, free safety equipment, training, etc. The latter is the notional administrative expense when someone leaves.

Subcontract premium is the premium incurred over and above direct variable cost when one standard hour of work is subcontracted.

Table 7.12

2.3. Marketing

The information from marketing is used to generate the requirement for capacity and to help evaluate the relative merits of increases in sales and capacity.

Of all the departments supplying data, marketing revises its estimates most frequently, probably monthly, and is the source of most requests for sensitivity analyses, e.g. what happens if the export order from Brazil comes through?, when is the soonest we could make a few more drills?, and so forth. These are the situations in which management wants reassurance that meeting the orders is profitable, rather than accepting the sales-oriented rule-of-thumb 'if it's feasible, make it'.

Marketing is responsible for supplying the data on:

. sales forecasts

. retail price and distributor discounts

. opening inventory at the start of the planning period

. finished machines inventory policy,

and the forms are illustrated in Table 7.13 overleaf.

2.4. General

These forms only suggest the sources of information. Some person, some department in the organisation should be responsible for planning and controlling these variables. If the source I have suggested pleads ignorance or indifference, then the rightful owner must be tracked down. It could be that several departments claim ownership; for instance, finished machines inventory is held for a variety of reasons, the factory uses it as stored capacity, while marketing wants a buffer against the unexpected. One of the best ways to help resolve conflicts is to evaluate the consequences of the two policies, and hope that profit figures speak louder than prejudices.

Before leaving data collection and going on to data conversion, I must point out that this is not an exhaustive list of the data required. It does indicate the type of data available at B.D.R. to form a suitable basis of a resource allocation model.

Table 7.13

UNIT SALES, INVENTORY AND PRICE SUMMARY

ESTIMATES FROM: NOVEMBER '71 TO NOVEMBER '72

SALES

	START	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
FWD		10	20	35	40	35	65	35	35	55	44	38	47	51
DRILL		100	161	190	190	108	22	4	99	131	85	50	-	120
LOADER		86	79	117	118	110	135	89	110	99	74	68	85	90
DIGGER		235	184	210	237	259	235	208	201	181	162	127	158	220
F.M.I. - MIN.														
FWD	5	10	18	20	18	33	18	18	27	22	19	23	25	10
DRILL	67	80	95	95	54	11	2	50	65	42	25	-	60	80
LOADER	154	40	58	59	55	67	45	55	50	37	34	42	45	40
DIGGER	100	92	105	118	129	117	104	100	90	81	63	78	110	92

SELLING PRICES & CNR

PRODUCTS

	FWD	DRILL	LOADER	DIGGER
	£	£	£	£
Retail Price	4536.0	435.0	489.0	1409.0
Distributor Discount	680.0	65.0	73.0	211.0
Company Net Return	3856.0	370.0	416.0	1198.0

NOTES

F.M.I. - Finished Machines Inventory

However, additional data will be necessary before the model can be used to help solve problems created by the unique combination of events that characterise each planning exercise. The new data may be as trivial as revising the sales forecast or inventory policy, or the more substantial process of adding a new product or productive department.

3. DATA CONVERSION

3.1. Introduction

The awareness that data conversion is necessary is an important step in the process of setting up a planning system. All too often tactical planning is seen merely as the extension of operations planning.

This mistaken approach to tactical planning overlooks the fact that departmental data is often generated, aggregated, recorded, processed and presented with the objectives of the department in mind. Much is heard in management science circles about the classic pitfall of sub-optimisation, without mention of the fact that changing the scale of processing, substituting a company objective for a departmental one, is only part of the story. The point is that the raw data generated by the departments is often not suitable for corporate tactical planning because the departmental objectives have biased the data, not in any sinister way, but as a natural consequence of the process of systems analysis done at the level of the department. See Appendix 2 for full details.

Mere departmental data can be inadequate on a number of counts:

. Detail - the basic data may be perfectly sound, but the degree of aggregation wrong. This is not serious if the data is too detailed; on the other hand, the need for a different breakdown or more detail can present considerable obstacles. For example, production control keeps a record of departmental standard hours for labour loading. The data serves their particular purpose reasonably well. However, for corporate planning the departmental hours need to be adjusted for wasted labour and the departments need to be subdivided into major machine groups.

. Assumptions - the adage goes 'I believe that I may understand, not, I understand that I man believe'. The assumptions that lie behind the data for operations planning may be irrelevant for tactical planning. A certain amount of questioning is necessary to ensure that the grosser errors come to light. This implies that the corporate planning group has, at the very least, a working knowledge of the activities and technology of the rest of the organisation. An example is one of the assumptions that is used in the calculation of standard costs: a constant relationship is assumed between products and men, thus:

product ⟶ standard hours ⟶ clock hours ⟶ men

Of course, the whole sequence is riddled with assumptions about productivity, design changes, and so forth, but the least plausible and most important is the last:

clock hours ⟶ men

While this is true in the upward direction, as production is increased more labour is used, it is not true in the downward, as production falls off labour is not necessarily reduced pari passu.

The problem is that the planned cost of direct labour is derived from production plans and goes into 'cost of goods sold' (and inventory), it is not calculated from manpower schedules. Moreover, putting the whole cost of direct labour against the product does not allow management to weigh up the consequences of having men temporarily underemployed. The error is to classify as directly variable per unit of product an expense which, in fact, varies directly with the number of attendance hours.

- Omissions - the data provided by the departments is invariably of an operational nature. The factors to be weighed and the room for manoeuvre are not necessarily the same for both tactical planning and operations planning. This suggests that certain data required for tactical planning may not be available, e.g. the costs of hiring and firing. These costs were established by (a) going through the records of the personnel department to check the invoices for advertisements for direct labour (the accounts lost this figure amongst advertising in general), (b) asking the shop floor supervisors about their training practices, (c) asking the cost section for information on 'make-up' pay, and (d) enquiring from the factory safety department about the free issue of overalls, boots and goggles.
- Interactions - many of the important linkages remain unperceived or unquantified, for whatever reasons: difficulties with processing, complexity or ignorance.

With the preamble out of the way I turn to the details of data conversion.

3.2. Production Data

References are given to trace the raw data back to the tables in the earlier part of this appendix.

The first adjustment is to the departmental standard hours in order that they show the true capacity required to produce one unit of each product. The basic data is in Tables 7.1 and 7.2.

ADJUSTED DEPARTMENTAL STANDARD HOURS

	Primary	Secondary	Assembly	Total
F.W.D.	50.56	152.70	97.13	300.39
Drill	19.36	49.60	67.17	136.13
Loader	13.36	86.51	14.91	114.78
Digger	24.43	147.91	54.10	226.44

Table 7.14

The mechanics of the calculations are to increase the original estimates of departmental standard hours, first to allow for the production of spares and then for wasted labour.

Taking the figure for the standard hours of the F.W.D. in the primary department:

$$\underbrace{48.05}_{\text{original estimate}} \times \frac{1}{1-\underbrace{.04}_{\text{spares rate}}} = \underbrace{50.05}_{\text{adjusted for spares}} \times \frac{1}{1-\underbrace{.01}_{\text{scrap rate}}} = \underbrace{50.56}_{\text{adjusted for scrap}}$$

In other words, the motive is to discover the labour input required for one unit of output.

The next step is to calculate the capacity available per man on normal time, and two rates of overtime. Here the original data concerns the proportion of men on nights, the efficiency and so forth. Having decided to work in standard hours (the capacity required is expressed in these units), the equations for November in the primary department, using Tables 7.2, 7.3 and 7.4 are:

(a) Normal attendance hours - 40 hour week

	a days/ month	b hours/ day	c average attend. hours avail./man a X b	d standard hour performance	e std.hours avail./man /month c X d
Primary	20	8	160	2.07	331
Secondary				2.20	352
Assembly				2.55	408

(b) Overtime at 1 1/2 - Friday night and Saturday morning

	f % on shift	g ovt.hrs. avail./ week	h average hrs.avail. /man/week f X g	i prop.out. avail./man /week h ÷ 40	j std.hours avail./man /month e X i	
Days	60	5	7	0.175	58	Prim.
Nights	40	10			62	Secd.
					71	Assy.

(c) Overtime at 2 - Sunday, dayshift only

	k % on shift	l ovt.hrs. avail./ week	m average hrs.avail. /man/week k ✕ l	n prop.ovt. avail./man /week m ÷ 40	o std.hours avail./man /month e ✕ n	
Days	60	4	2.4	0.06	20	Prim.
					21	Secd.
					24	Assy.

It should be remembered that the objective of these calculations is to establish the size of the tranches of capacity available. Each tranche is successively more expensive. Table 7.15 gives the results for the whole planning period.

The last factor limiting production is the 'jigs and fixtures' restraint. This is expressed as the maximum production per day of individual products and of groups of products, when there are shared special purpose production facilities. In this case it is only necessary to convert the daily rate into the corresponding figure for each month of the planning period. Table 7.16 illustrates the results of the process.

3.3. Cost Data

The motive is to identify the costs which vary directly with each variable: products, manpower, etc., in order to establish the true marginal cost of the decision variables.

Table 7.15

STANDARD HOURS AVAILABLE PER MAN EACH MONTH

Estimates: from Nov. '71 to Nov. '72

	Month	Nov A	Dec B	Jan C	Feb D	Mar E	Apr F	May G	Jun H	Jul I	Aug J	Sep K	Oct L	Nov M
	Days	20	22	20	20	24	19	20	20	15	15	24	20	20
NORMAL TIME	Perf													
Primary	207%	331	364	331	331	397	315	331	331	248	248	395	331	331
Secondary	220%	352	387	352	352	422	334	352	352	264	264	420	352	352
Assembly	255%	408	449	408	408	490	388	408	408	306	306	487	408	408
Attendance hours/man		160	176	160	160	192	152	160	160	120	120	191	160	160
OVERTIME at: 1 1/2														
Primary		58	64	58	58	69	55	58	58	43	43	69	58	58
Secondary		62	68	62	62	74	58	62	62	46	46	74	62	62
Assembly		71	79	71	71	86	68	71	71	54	54	85	71	71
Attendance hours/man		28	31	28	28	34	27	28	28	21	21	33	28	28
OVERTIME at: 2														
Primary		20	22	20	20	24	19	20	20	15	15	24	20	20
Secondary		21	23	21	21	25	20	21	21	16	16	25	21	21
Assembly		24	27	24	24	29	23	24	24	18	18	29	24	24
Attendance hours/man		9.6	10.6	9.6	9.6	11.5	9.1	9.6	9.6	7.2	7.2	11.5	9.6	9.6

Table 7.16

MAXIMUM RATES OF PRODUCTION

	MAX DAILY RATE	MONTH	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
		CODE	A	B	C	D	E	F	G	H	I	J	K	L	M
INDIVIDUAL PRODUCTS															
FWD	2.0		40	44	40	40	48	38	40	40	30	30	48	40	40
DRILL	7.5		150	165	150	150	180	143	150	150	113	113	180	80	150
LOADER	5.0		100	110	100	100	120	95	100	100	75	75	130	100	100
DIGGER	10.5		210	231	210	210	252	200	210	210	158	158	252	210	210
BUCKET	3.2		64	70	64	64	77	61	64	64	48	48	77	64	64
GROUPS OF PRODUCTS															
DRILL LOADER	10.0		200	220	200	200	240	190	200	200	150	150	240	200	200

EXPLANATION:

These restrictions represent the most severe limits on the rate of production. If, for any particular product, the restriction was removed by further investment in special purpose equipment, it would be necessary to ask production control for data on the next most severe restriction and include that in the model.

The figures are based on the maximum capacity for 80 hours per week, two shifts, and makes no allowance for overtime working. If a particular constraint becomes active, parametric programming can be used to relax it so as to include the capacity available on overtime.

A product can be in one of three categories:

- finished machines inventory
- production
- sales

Product costs recorded by the company, direct variable costs, include freight and some labour charges which are not directly proportional to the level of production.

Freight expenses are incurred when products are shipped, not when they are produced. The other correction is a little more complex.

There are three components to the payment of direct labour:

- day wage
- premium
- bonus

The first is for being present, irrespective of when this is or whether any work is done. The second is for when the man is present: nights, overtime. The last is for the rate of working, the productivity. Premiums are not included in direct variable cost; they are classified as an indirect (period) cost. However, the other two are included. It is reasonable to assume that when a man is working he does so at his customary rate. In other words, when products are made, bonus costs are incurred - the bonus is rightly classified as directly variable. On the other hand, the day wage has nothing to do with the level of production, it is a payment for being present, not for working. Therefore the day wage component must be taken out of the standard direct variable cost as recorded by the costing system.

The adjustment is made by using a similar process to that by which the standard costs were built up:

standard hours $\longrightarrow$ clock hours $\times$ day wage rate $=$ day wage element in d.v.c.

The first link, from standard hours to clock hours, employs the standard hour performance. The calculation is based on the total standard hours for each product, rather than the departmental figures, and an average of the standard hour performances. The result is marginally different from that obtained from the individual departmental calculations.

UNIT MARGINAL COST SUMMARY

	a std.cost	b freight (in a)	c std.hrs.	d clock hours c ÷ 227	e day wage element d × £.4	adjusted d.v.c. a-b-e
	£	£	hours	hours	£	£
F.W.D.	2436.4	47.0	279.6	123.2	49.3	2340.1
Drill	216.2	8.9	128.5	56.6	22.6	184.7
Loader	213.7	6.3	104.6	46.1	18.4	189.0
Digger	645.7	10.6	208.3	91.8	36.7	598.4

Table 7.17

Reference Tables 7.1, 7.2, 7.8, 7.9, 7.10

The inventory carrying cost is calculated next. This is based on the original direct variable cost, excluding freight. The carrying cost is related to the length of the period and not to the number of working days. Since the year is divided into four and five week periods there are only two costs to be calculated for each product.

UNIT INVENTORY COST SUMMARY

	a std.cost	b freight	c adjusted std.cost a − b	inventory cost 4 week c × .0154	 5 week c × .0192
	£	£	£	£	£
F.W.D.	2436.4	47.0	2389.4	36.8	45.9
Drill	216.2	8.9	207.3	3.2	4.0
Loader	213.7	6.3	207.4	3.2	4.0
Digger	645.7	10.6	635.1	9.8	12.2

Table 7.18

Reference Tables 7.8 and 7.12

And finally the freight charge is treated as an expense incurred when the product is sold and shipped.

UNIT COMPANY NET RETURN SUMMARY

	company net return	freight	adjusted company net return
	£	£	£
F.W.D.	3856.0	47.0	3809.0
Drill	370.0	8.9	361.0
Loader	416.0	6.3	409.7
Digger	1198.0	10.6	1187.4

Table 7.19

Reference Tables 7.8 and 7.13

Having identified one of the costs that is proportional to the number of attendance hours, the day wage, it is necessary to calculate the other costs that vary in a similar manner.

To be precise, there are three types of cost that vary with manpower:

. costs that are directly proportional to the number of men, for example fringe benefits

. costs that are directly proportional to the number of hours, - the day wage

. costs that, given knowledge of when the hours are worked, are directly proportional to the number of hours, - the premiums.

The cost of having a man available for work each month is made up of fringe benefits, night shift premium, and day wage. This is called the cost of normal time. It is the basic cost of employing a man. If the man does any work other costs will be incurred: bonuses and perhaps overtime premiums.

Of the last two, the former is part of the cost of production and the latter part of the cost of overtime working, neither have anything to do with the decision of whether or not to employ another man. This process of putting costs against the variables which generate them is vital if the relative merits of different policies are to be compared.

Table 7.20 shows the calculation of labour costs for the whole period. The entries are explained below:

(a) normal time - this is the 'average attendance hours available per man/month' - as shown in Table 7.15.

- the day wage cost is simply the day wage (Ł.4) multiplied by the hours available in each month

Table 7.20

CALCULATION OF LABOUR COSTS

Estimates: From Nov. '71 to Nov. '72

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Month	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Week	4	5	4	4	5	4	4	5	4	4	5	4	4
NORMAL TIME	A	B	C	D	E	F	G	H	I	J	K	L	M
Day Wage	64.0	70.4	64.0	64.0	76.8	60.8	64.0	64.0	48.0	48.0	76.4	64.0	64.0
Night Shift Premium	8.4	9.3	8.4	8.4	10.1	8.0	8.4	8.4	6.3	6.3	10.1	8.4	8.4
Fringe Benefits	10.0	12.5	10.0	10.0	12.5	10.0	10.0	32.4	29.9	29.9	12.5	10.0	10.0
TOTAL	82.4	92.2	82.4	82.4	99.4	78.8	81.4	104.8	84.2	84.2	99.0	82.4	82.4
Attendance hours/man	160	176	160	160	192	152	160	160	120	120	191	160	160
OVERTIME at: 1 1/2													
Day Wage	11.2	12.4	11.2	11.2	13.6	10.8	11.2	11.2	8.4	8.4	13.2	11.2	11.2
Overtime Premium	5.6	6.2	5.6	5.6	6.8	5.4	5.6	5.6	4.2	4.2	6.6	5.6	5.6
TOTAL	16.8	18.6	16.8	16.8	20.4	16.2	16.8	16.8	12.6	12.6	19.8	16.8	16.8
Attendance hours/man	28	31	28	28	34	27	28	28	21	21	33	28	28
OVERTIME at: 2													
Day Wage	3.8	4.2	3.8	3.8	4.6	3.6	3.8	3.8	2.9	2.9	4.6	3.8	3.8
Overtime Premium	3.8	4.2	3.8	3.8	4.6	3.6	3.8	3.8	2.9	2.9	4.6	3.8	3.8
TOTAL	7.6	8.4	7.6	7.6	9.2	7.2	7.6	7.6	5.8	5.8	9.2	7.6	7.6
Attendance hours/man	9.6	10.6	9.6	9.6	11.5	9.1	9.6	9.6	7.2	7.2	11.5	9.6	9.6

- the night shift premium is calculated as follows:

Day Wage	x	N.S. Premium	x	Proportion of men on N.S.	x	Attendance hours available/man	
£.4	x	.33	x	.4	x	160	= £8.5

(b) overtime at 1 1/2 - 10 hours on Friday night (the nightshift receive the overtime premium but not the nightshift premium), and five hours on Saturday morning for the dayshift

- the day wage - as above
- the overtime premium is calculated as in the example:

Day Wage	x	Overtime Premium	x	Attendance hours available/man	
£.4	x	.5	x	28	= £5.6

(c) overtime at 2 - although there are 8 hours of overtime at this rate potentially available, 4 are reserved to meet operational problems. This leaves 4 hours at the discretion of tactical planning:

- the day wage - as above
- the overtime premium - since this is 'double time' it means that the premium equals the day wage.

4. DEFINITIONS

Standard Hour

An average man working at a normal and sustainable rate for 1 clock hour will produce 1 standard hour of output.

Standard Hours per Product

The labour content of a product is the sum of the 'floor to floor' times of all its component parts. The floor to floor or 'allowed' time of a part (or operation) is established by time study methods and assumes a certain normal rate of working - as mentioned above. Since an allowed time is established for each distinct operation, it is a simple matter to derive the work generated in each department by the completion of 1 unit of finished product - this summary is given in Table 7.1 called Departmental Standard Hours.

Standard Hour Performance

The factor which links the actual output of the average man and the theoretical output of the normal man is called the Standard Hour Performance. There is a large discrepancy between the labour content of a product measured in standard hours, and its labour content measured in clock hours. This discrepancy is caused by two factors: in the first place, the allowed time is particularly generous, and secondly, the average man works harder than normal because of the bonus element of the piece rate system. These two factors together make it plausible for a man to produce 2.5 standard hours of output in 1 clock hour. We would say, in this case, that the standard hour performance was 2.5 or 250%.

Scrap Rate and Spares

The scrap rate of an individual department is the amount of labour expended on parts that are subsequently scrapped. Because of the huge number of parts and the different routings through, say, seven productive departments, it is impracticable to attempt to adjust the labour inputs for a department to compensate for subsequent wastage in other departments further down stream in the manufacturing process.

Production control increase the size of each batch of parts for the production of spares. This is achieved by a straight percentage increase on the size of the batch scheduled for finished products. The figure represents the percentage of the batch that will be used for spares.

Direct Material

This is made up of: vendor price, packing, import duty (where applicable), overseas inland freight, ocean freight, inland freight for U.K., miscellaneous materials (paint, petrol, etc.), subcontract premium, literature.

Direct Labour

The standard cost is divided into three: basic standard time for primary operations and for assembly operations and the standard rate. The components of the first are: pick-up pieces from tote tray, pick-up and lay-aside single pieces, load and unload, process time, clean fixtures, operator check piece, tool change allowance, tool adjustment allowance, material handling (by operator), move to next machine centre, personal - fatigue - auxiliary. The second establishes the cost of assembly operations. The third, standard rate, is the departmental bonus element.

Direct Labour Operating Allowances

A standard rate is established for each department comprising: training time, waiting and idle time, process waiting time associated with multiple assignments, non-standard work, make-up time, fitting shortages, clocking allowance, rectification and off-line repair for assembly lines.

Processing Supplies and Scrap

These are such items as: welding gases, oxygen, cutting oils, acids, shot, sand, cutting tools, grinding wheels, abrasives.

Make-Up Pay

When a worker is unable to earn bonuses, through no fault of his own, his wage is 'made-up' to the average level of the other workers in the same department. There are many reasons why he might be prevented from earning bonuses: the operation has no agreed 'allowed time'; the raw material is of the wrong specification; the machine will not reach its designed performance level, etc.

APPENDIX 8

CONSTRUCTION & RUNNING

CONTENTS

1. CODING SYSTEM

The program, MPS/360, requires the naming of columns and rows. Variable names can be from 1 to 8 characters in length (alphameric, no embedded blanks). For ease in punching cards, reading the output and writing the report-generating program, all names use the whole field of 8 characters. It is best not to use any special characters (slash, dollar, etc.) in a variable name as they tend to have pre-empted meanings in computer programs (delimiter, multiplication, etc.).

The following pages describe the system.

1. COLUMN VARIABLES - start punching in card column 5

The first column identifies the main categories of variables

P	production and inventory
M	monthly sales
D	department

Production - Columns 2 through 6 inclusive define the product

F W D T R	four wheel drive tractor
T R A L R	drill
L O A D R	loader
D I G G R	digger

- Column 7 distinguishes between production and finished machines inventory

P	production
I	inventory

Monthly Sales - Columns 2 through 6 as for production above

- Column 7 is padded

P

Department - Columns 2 through 6 define the department

H T R T T	primary department
W E L D G	secondary department
A S S L Y	assembly department

- Column 7 distinguishes between the different tranches of capacity and defines the variables for the changes in the size of departments

N	normal working week
X	overtime at 1 1/2
Z	overtime at 2
S	subcontract
U	increases in size of department
D	decreases in size of department

The last column defines the month. An alpha code is preferable to numeric

$$\left.\begin{matrix} A \\ \vdots \\ M \end{matrix}\right\} \text{month}$$

1.1. Examples of Column Names

P F W D T R P A	- production of F.W.D.'s in November 1971
M T R A L R P M	- sales of drills in November 1972
P L O A D R I F	- inventory of loaders in April
D W E L D G N H	- number of men in secondary dept. in June
D A S S L Y Z C	- number of men working Sunday overtime in assembly in January

D H T R T T U K - number of men who joined primaries at the beginning of September

D W E L D G S B - number of men's worth of work subcontracted for welding in December

D H T R T T D I - number of men who left primaries at the beginning of August

D A S S L Y X C - number of men working overtime at 1 1/2 during January

2. ROW NAMES - start punching in card column 15

The first column identifies the variable as being the name of an equation or row

S row name

The last column identifies the time period, as for columns

A
} month
M

The other columns identify the types of equations

Sales Restriction - Columns 2 through 5 inclusive define the products

F W D T	four wheel drive tractor
T R A L	drill
L O A D	loader
D I G G	digger

- Columns 6 and 7 indicate potential sales

P S sales

Production, Sales, Inventory identity - Columns 2 through 5 inclusive are identical to the definition of products in the sales restriction above

- Columns 6 and 7 distinguish these as monthly production, inventory, sales identities

M S monthly production, sales, inventory identities

Material Restriction - Columns 2 through 7 inclusive define the row name for this restriction

H Y D R A M hydraulic ram restriction

Capacity Restriction - For total capacity, columns 2 through 7 inclusive identify the equations

H T R T M T primary department
W E L D N G secondary department
A S S M L Y assembly department

- For the premium tranches of capacity, columns 2 through 6 define the departments

H T R T T primary
W E L D G secondary
A S S L Y assembly

- Column 7 defines the premium capacity tranches as before

X overtime at 1 1/2

Z overtime at 2

Manpower Changes, Identity - Columns 2 through 6 define the departments as for the premium tranches of capacity

- Column 7 specifies a balance equation for manpower changes

C balance equation

Manpower Changes, Rates - Columns 2 through 6 define the departments as above

- Column 7 identifies whether the change is upwards or downwards

U upwards

D downwards

2.1. Examples of Row Names

S F W D T P S A - potential sales of F.W.D.'s in November 1971

S D I G G M S L - production, inventory, sales identity for diggers in October

S H Y D R A M E - cumulative supply of rams to the end of March

S H T R T M T I	- total capacity in primaries during July
S W E L D G X K	- capacity in secondzry for overtime at 1 1/2 in September
S A S S L Y Z F	- capacity in assembly for overtime at 2 in April
S W E L D G C J	- balance equation for changes in manpower for secondary in August
S H T R T T U C	- restriction in rate of increase in manpower for primary between December and January
S A S S L Y D D	- restriction on rate of decrease in manpower for assembly between January and February

2. INPUT LISTING

The following pages in this section contain a complete listing of the input data deck for the MPS/360 program.

The data refers to the factory strike. The furthest left-hand column corresponds to card column 1 of a punch card. Each column of print corresponds to the appropriate card column, numbering from the left. Punching up a deck from this listing will therefore reproduce the results in Appendices 5 and 6.

For the OS/360 and MPS/360 job control and control language program cards necessary to run the program, reference should be made to the relevant IBM manuals listed in the bibliography.

To generate the one-page summary report, the report-writing program listed in section 3 is necessary.

FACTORY STRIKE IN MARCH

```
NAME          ELEC
ROWS
 L  SHTRTMTA
 L  SWELDNGA
 L  SASSMLYA
 L  SHTRTTXA
 L  SWELDGXA
 L  SASSLYXA
 L  SHTRTTZA
 L  SWELDGZA
 L  SASSLYZA
 L  SHYDRAMA
 E  SFWDTMSA
 E  STRALMSA
 E  SLOADMSA
 E  SDIGGMSA
 L  SFWDTPSA
 L  STRALPSA
 L  SLOADPSA
 L  SDIGGPSA
 L  SHTRTMTB
 L  SWELDNGB
 L  SASSMLYB
 L  SHTRTTXB
 L  SWELDGXB
 L  SASSLYXB
 L  SHTRTTZB
 L  SWELDGZB
 L  SASSLYZB
 L  SHYDRAMB
 E  SFWDTMSB
 E  STRALMSB
 E  SLOADMSB
 E  SDIGGMSB
 L  SFWDTPSB
 L  STRALPSB
 L  SLOADPSB
 L  SDIGGPSB
 E  SHTRTTCB
 E  SWELDGCB
 E  SASSLYCB
 G  SHTRTTUB
 G  SWELDGUB
 G  SASSLYUB
 G  SHTRTTDB
 G  SWELDGDB
 G  SASSLYDB
 L  SHTRTMTC
 L  SWELDNGC
 L  SASSMLYC
 L  SHTRTTXC
 L  SWELDGXC
 L  SASSLYXC
 L  SHTRTTZC
```

INPUT LISTING

FACTORY STRIKE IN MARCH

```
L   SWELDGZC
L   SASSLYZC
L   SHYDRAMC
E   SFWDTMSC
E   STRALMSC
E   SLOADMSC
E   SDIGGMSC
L   SFWDTPSC
L   STRALPSC
L   SLOADPSC
L   SDIGGPSC
E   SHTRTTCC
E   SWELDGCC
E   SASSLYCC
G   SHTRTTUC
G   SWELDGUC
G   SASSLYUC
G   SHTRTTDC
G   SWELDGDC
G   SASSLYDC
L   SHTRTMTD
L   SWELDNGD
L   SASSMLYD
L   SHTRTTXD
L   SWELDGXD
L   SASSLYXD
L   SHTRTTZD
L   SWELDGZD
L   SASSLYZD
L   SHYDRAMD
E   SFWDTMSD
E   STRALMSD
E   SLOADMSD
E   SDIGGMSD
L   SFWDTPSD
L   STRALPSD
L   SLOADPSD
L   SDIGGPSD
E   SHTRTTCD
E   SWELDGCD
E   SASSLYCD
G   SHTRTTUD
G   SWELDGUD
G   SASSLYUD
G   SHTRTTDD
G   SWELDGDD
G   SASSLYDD
L   SHTRTMTE
L   SWELDNGE
L   SASSMLYE
L   SHTRTTXE
L   SWELDGXE
L   SASSLYXE
L   SHTRTTZE
```

FACTORY STRIKE IN MARCH

```
L   SWELDGZE
L   SASSLYZE
L   SHYDRAME
E   SFWDTMSE
E   STRALMSE
E   SLOADMSE
E   SDIGGMSE
L   SFWDTPSE
L   STRALPSE
L   SLOADPSE
L   SDIGGPSE
E   SHTRTTCE
E   SWELDGCE
E   SASSLYCE
G   SHTRTTUE
G   SWELDGUE
G   SASSLYUE
G   SHTRTTDE
G   SWELDGDE
G   SASSLYDE
L   SHTRTMTF
L   SWELDNGF
L   SASSMLYF
L   SHTRTTXF
L   SWELDGXF
L   SASSLYXF
L   SHTRTTZF
L   SWELDGZF
L   SASSLYZF
L   SHYDRAMF
E   SFWDTMSF
E   STRALMSF
E   SLOADMSF
E   SDIGGMSF
L   SFWDTPSF
L   STRALPSF
L   SLOADPSF
L   SDIGGPSF
E   SHTRTTCF
E   SWELDGCF
E   SASSLYCF
G   SHTRTTUF
G   SWELDGUF
G   SASSLYUF
G   SHTRTTDF
G   SWELDGDF
G   SASSLYDF
L   SHTRTMTG
L   SWELDNGG
L   SASSMLYG
L   SHTRTTXG
L   SWELDGXG
L   SASSLYXG
L   SHTRTTZG
```

FACTORY STRIKE IN MARCH

```
L   SWELDGZG
L   SASSLYZG
L   SHYDRAMG
E   SFWDTMSG
E   STRALMSG
E   SLOADMSG
E   SDIGGMSG
L   SFWDTPSG
L   STRALPSG
L   SLOADPSG
L   SDIGGPSG
E   SHTRTTCG
E   SWELDGCG
E   SASSLYCG
G   SHTRTTUG
G   SWELDGUG
G   SASSLYUG
G   SHTRTTDG
G   SWELDGDG
G   SASSLYDG
L   SHTRTMTH
L   SWELDNGH
L   SASSMLYH
L   SHTRTTXH
L   SWELDGXH
L   SASSLYXH
L   SHTRTTZH
L   SWELDGZH
L   SASSLYZH
L   SHYDRAMH
E   SFWDTMSH
E   STRALMSH
E   SLOADMSH
E   SDIGGMSH
L   SFWDTPSH
L   STRALPSH
L   SLOADPSH
L   SDIGGPSH
E   SHTRTTCH
E   SWELDGCH
E   SASSLYCH
G   SHTRTTUH
G   SWELDGUH
G   SASSLYUH
G   SHTRTTDH
G   SWELDGDH
G   SASSLYDH
L   SHTRTMTI
L   SWELDNGI
L   SASSMLYI
L   SHTRTTXI
L   SWELDGXI
L   SASSLYXI
L   SHTRTTZI
```

INPUT LISTING

FACTORY STRIKE IN MARCH

```
L  SWELDGZI
L  SASSLYZI
L  SHYDRAMI
E  SFWDTMSI
E  STRALMSI
E  SLOADMSI
E  SDIGGMSI
L  SFWDTPSI
L  STRALPSI
L  SLOADPSI
L  SDIGGPSI
E  SHTRTTCI
E  SWELDGCI
E  SASSLYCI
G  SHTRTTUI
G  SWELDGUI
G  SASSLYUI
G  SHTRTTDI
G  SWELDGDI
G  SASSLYDI
L  SHTRTMTJ
L  SWELDNGJ
L  SASSMLYJ
L  SHTRTTXJ
L  SWELDGXJ
L  SASSLYXJ
L  SHTRTTZJ
L  SWELDGZJ
L  SASSLYZJ
L  SHYDRAMJ
E  SFWDTMSJ
E  STRALMSJ
E  SLOADMSJ
E  SDIGGMSJ
L  SFWDTPSJ
L  STRALPSJ
L  SLOADPSJ
L  SDIGGPSJ
E  SHTRTTCJ
E  SWELDGCJ
E  SASSLYCJ
G  SHTRTTUJ
G  SWELDGUJ
G  SASSLYUJ
G  SHTRTTDJ
G  SWELDGDJ
G  SASSLYDJ
L  SHTRTMTK
L  SWELDNGK
L  SASSMLYK
L  SHTRTTXK
L  SWELDGXK
L  SASSLYXK
L  SHTRTTZK
```

FACTORY STRIKE IN MARCH

```
L  SWELDGZK
L  SASSLYZK
L  SHYDRAMK
E  SFWDTMSK
E  STRALMSK
E  SLOADMSK
E  SDIGGMSK
L  SFWDTPSK
L  STRALPSK
L  SLOADPSK
L  SDIGGPSK
E  SHTRTTCK
E  SWELDGCK
E  SASSLYCK
G  SHTRTTUK
G  SWELDGUK
G  SASSLYUK
G  SHTRTTDK
G  SWELDGDK
G  SASSLYDK
L  SHTRTMTL
L  SWELDNGL
L  SASSMLYL
L  SHTRTTXL
L  SWELDGXL
L  SASSLYXL
L  SHTRTTZL
L  SWELDGZL
L  SASSLYZL
L  SHYDRAML
E  SFWDTMSL
E  STRALMSL
E  SLOADMSL
E  SDIGGMSL
L  SFWDTPSL
L  STRALPSL
L  SLOADPSL
L  SDIGGPSL
E  SHTRTTCL
E  SWELDGCL
E  SASSLYCL
G  SHTRTTUL
G  SWELDGUL
G  SASSLYUL
G  SHTRTTDL
G  SWELDGDL
G  SASSLYDL
L  SHTRTMTM
L  SWELDNGM
L  SASSMLYM
L  SHTRTTXM
L  SWELDGXM
L  SASSLYXM
L  SHTRTTZM
```

INPUT LISTING

FACTORY STRIKE IN MARCH

```
 L  SWELDGZM
 L  SASSLYZM
 L  SHYDRAMM
 E  SFWDTMSM
 E  STRALMSM
 E  SLOADMSM
 E  SDIGGMSM
 L  SFWDTPSM
 L  STRALPSM
 L  SLOADPSM
 L  SDIGGPSM
 E  SHTRTTCM
 E  SWELDGCM
 E  SASSLYCM
 G  SHTRTTUM
 G  SWELDGUM
 G  SASSLYUM
 G  SHTRTTDM
 G  SWELDGDM
 G  SASSLYDM
 N  ENTRPREN
COLUMNS
    PFWDTRIZ  SFWDTMSA        1.00000
    PTRALRIZ  STRALMSA        1.00000
    PLOADRIZ  SLOADMSA        1.00000
    PDIGGRIZ  SDIGGMSA        1.00000
    PFWDTRPA  SHTRTMTA       50.56000   SWELDNGA      152.70000
    PFWDTRPA  SASSMLYA       97.13000   SFWDTMSA        1.00000
    PFWDTRPA  ENTRPREN   - 2340.12000
    PTRALRPA  SHTRTMTA       19.36000   SWELDNGA       49.60000
    PTRALRPA  SASSMLYA       67.17000   SHYDRAMA        1.00000
    PTRALRPA  SHYDRAMB        1.00000   SHYDRAMC        1.00000
    PTRALRPA  SHYDRAMD        1.00000   SHYDRAME        1.00000
    PTRALRPA  SHYDRAMF        1.00000   SHYDRAMG        1.00000
    PTRALRPA  SHYDRAMH        1.00000   SHYDRAMI        1.00000
    PTRALRPA  SHYDRAMJ        1.00000   SHYDRAMK        1.00000
    PTRALRPA  SHYDRAML        1.00000   SHYDRAMM        1.00000
    PTRALRPA  STRALMSA        1.00000   ENTRPREN  -   184.65000
    PLOADRPA  SHTRTMTA       13.36000   SWELDNGA       86.51000
    PLOADRPA  SASSMLYA       14.91000   SHYDRAMA        1.00000
    PLOADRPA  SHYDRAMB        1.00000   SHYDRAMC        1.00000
    PLOADRPA  SHYDRAMD        1.00000   SHYDRAME        1.00000
    PLOADRPA  SHYDRAMF        1.00000   SHYDRAMG        1.00000
    PLOADRPA  SHYDRAMH        1.00000   SHYDRAMI        1.00000
    PLOADRPA  SHYDRAMJ        1.00000   SHYDRAMK        1.00000
    PLOADRPA  SHYDRAML        1.00000   SHYDRAMM        1.00000
    PLOADRPA  SLOADMSA        1.00000   ENTRPREN  -   188.97000
    PDIGGRPA  SHTRTMTA       24.43000   SWELDNGA      147.91000
    PDIGGRPA  SASSMLYA       54.10000   SDIGGMSA        1.00000
    PDIGGRPA  ENTRPREN   -  598.39000
    MFWDTRPA  SFWDTMSA   -    1.00000   SFWDTPSA        1.00000
    MFWDTRPA  ENTRPREN     3809.00000
    MTRALRPA  STRALMSA   -    1.00000   STRALPSA        1.00000
    MTRALRPA  ENTRPREN      361.10000
```

INPUT LISTING

FACTORY STRIKE IN MARCH

MLOADRPA	SLOADMSA	- 1.00000	SLOADPSA	1.00000
MLOADRPA	ENTRPREN	409.75000		
MDIGGRPA	SDIGGMSA	- 1.00000	SDIGGPSA	1.00000
MDIGGRPA	ENTRPREN	1187.40000		
PFWDTRIA	SFWDTMSA	- 1.00000	SFWDTMSB	1.00000
PFWDTRIA	ENTRPREN	- 36.80000		
PTRALRIA	STRALMSA	- 1.00000	STRALMSB	1.00000
PTRALRIA	ENTRPREN	- 3.20000		
PLOADRIA	SLOADMSA	- 1.00000	SLOADMSB	1.00000
PLOADRIA	ENTRPREN	- 3.20000		
PDIGGRIA	SDIGGMSA	- 1.00000	SDIGGMSB	1.00000
PDIGGRIA	ENTRPREN	- 9.80000		
DHTRTTNA	SHTRTMTA	- 331.00000	SHTRTTXA	- 1.00000
DHTRTTNA	SHTRTTCB	1.00000	SHTRTTUB	.11000
DHTRTTNA	SHTRTTDB	.01000	ENTRPREN	- 82.40000
DHTRTTXA	SHTRTMTA	- 58.00000	SHTRTTXA	1.00000
DHTRTTXA	SHTRTTZA	- 1.00000	ENTRPREN	- 16.80000
DHTRTTZA	SHTRTMTA	- 20.00000	SHTRTTZA	1.00000
DHTRTTZA	ENTRPREN	- 7.60000		
DHTRTTSA	SHTRTMTA	- 331.00000	ENTRPREN	- 274.00000
DWELDGNA	SWELDNGA	- 352.00000	SWELDGXA	- 1.00000
DWELDGNA	SWELDGCB	1.00000	SWELDGUB	.07000
DWELDGNA	SWELDGDB	.02000	ENTRPREN	- 82.40000
DWELDGXA	SWELDNGA	- 62.00000	SWELDGXA	1.00000
DWELDGXA	SWELDGZA	- 1.00000	ENTRPREN	- 16.80000
DWELDGZA	SWELDNGA	- 21.00000	SWELDGZA	1.00000
DWELDGZA	ENTRPREN	- 7.60000		
DWELDGSA	SWELDNGA	- 352.00000	ENTRPREN	- 287.00000
DASSLYNA	SASSMLYA	- 408.00000	SASSLYXA	- 1.00000
DASSLYNA	SASSLYCB	1.00000	SASSLYUB	.10000
DASSLYNA	SASSLYDB	.01000	ENTRPREN	- 82.40000
DASSLYXA	SASSMLYA	- 71.00000	SASSLYXA	1.00000
DASSLYXA	SASSLYZA	- 1.00000	ENTRPREN	- 16.80000
DASSLYZA	SASSMLYA	- 24.00000	SASSLYZA	1.00000
DASSLYZA	ENTRPREN	- 7.60000		
DASSLYSA	SASSMLYA	- 408.00000	ENTRPREN	- 323.00000
PFWDTRPB	SHTRTMTB	50.56000	SWELDNGB	152.70000
PFWDTRPB	SASSMLYB	97.13000	SFWDTMSB	1.00000
PFWDTRPB	ENTRPREN	- 2340.12000		
PTRALRPB	SHTRTMTB	19.36000	SWELDNGB	49.60000
PTRALRPB	SASSMLYB	67.17000	SHYDRAMB	1.00000
PTRALRPB	SHYDRAMC	1.00000	SHYDRAMD	1.00000
PTRALRPB	SHYDRAME	1.00000	SHYDRAMF	1.00000
PTRALRPB	SHYDRAMG	1.00000	SHYDRAMH	1.00000
PTRALRPB	SHYDRAMI	1.00000	SHYDRAMJ	1.00000
PTRALRPB	SHYDRAMK	1.00000	SHYDRAML	1.00000
PTRALRPB	SHYDRAMM	1.00000	STRALMSB	1.00000
PTRALRPB	ENTRPREN	- 184.65000		
PLOADRPB	SHTRTMTB	13.36000	SWELDNGB	86.51000
PLOADRPB	SASSMLYB	14.91000	SHYDRAMB	1.00000
PLOADRPB	SHYDRAMC	1.00000	SHYDRAMD	1.00000
PLOADRPB	SHYDRAME	1.00000	SHYDRAMF	1.00000
PLOADRPB	SHYDRAMG	1.00000	SHYDRAMH	1.00000
PLOADRPB	SHYDRAMI	1.00000	SHYDRAMJ	1.00000

INPUT LISTING

FACTORY STRIKE IN MARCH

PLOADRPB	SHYDRAMK		1.00000	SHYDRAML		1.00000
PLOADRPB	SHYDRAMM		1.00000	SLOADMSB		1.00000
PLOADRPB	ENTRPREN	-	188.97000			
PDIGGRPB	SHTRTMTB		24.43000	SWELDNGB		147.91000
PDIGGRPB	SASSMLYB		54.10000	SDIGGMSB		1.00000
PDIGGRPB	ENTRPREN	-	598.39000			
MFWDTRPB	SFWDTPSB		1.00000	SFWDTMSB	-	1.00000
MFWDTRPB	ENTRPREN		3809.00000			
MTRALRPB	STRALMSB	-	1.00000	STRALPSB		1.00000
MTRALRPB	ENTRPREN		361.10000			
MLOADRPB	SLOADMSB	-	1.00000	SLOADPSB		1.00000
MLOADRPB	ENTRPREN		409.75000			
MDIGGRPB	SDIGGMSB	-	1.00000	SDIGGPSB		1.00000
MDIGGRPB	ENTRPREN		1187.40000			
PFWDTRIB	SFWDTMSB	-	1.00000	SFWDTMSC		1.00000
PFWDTRIB	ENTRPREN	-	45.90000			
PTRALRIB	STRALMSB	-	1.00000	STRALMSC		1.00000
PTRALRIB	ENTRPREN	-	4.00000			
PLOADRIB	SLOADMSB	-	1.00000	SLOADMSC		1.00000
PLOADRIB	ENTRPREN	-	4.00000			
PDIGGRIB	SDIGGMSB	-	1.00000	SDIGGMSC		1.00000
PDIGGRIB	ENTRPREN	-	12.20000			
DHTRTTNB	SHTRTMTB	-	364.00000	SHTRTTXB	-	1.00000
DHTRTTNB	SHTRTTCB	-	1.00000	SHTRTTCC		1.00000
DHTRTTNB	SHTRTTUC		.11000	SHTRTTDC		.01000
DHTRTTNB	ENTRPREN	-	92.20000			
DHTRTTXB	SHTRTMTB	-	64.00000	SHTRTTXB		1.00000
DHTRTTXB	SHTRTTZB	-	1.00000	ENTRPREN	-	18.60000
DHTRTTZB	SHTRTMTB	-	22.00000	SHTRTTZB		1.00000
DHTRTTZB	ENTRPREN	-	8.40000			
DHTRTTSB	SHTRTMTB	-	364.00000	ENTRPREN	-	301.40000
DWELDGNB	SWELDNGB	-	387.00000	SWELDGXB	-	1.00000
DWELDGNB	SWELDGCB	-	1.00000	SWELDGCC		1.00000
DWELDGNB	SWELDGUC		.07000	SWELDGDC		.02000
DWELDGNB	ENTRPREN	-	92.20000			
DWELDGXB	SWELDNGB	-	68.00000	SWELDGXB		1.00000
DWELDGXB	SWELDGZB	-	1.00000	ENTRPREN	-	18.60000
DWELDGZB	SWELDNGB	-	23.00000	SWELDGZB		1.00000
DWELDGZB	ENTRPREN	-	8.40000			
DWELDGSB	SWELDNGB	-	387.00000	ENTRPREN	-	315.40000
DASSLYNB	SASSMLYB	-	449.00000	SASSLYXB	-	1.00000
DASSLYNB	SASSLYCB	-	1.00000	SASSLYCC		1.00000
DASSLYNB	SASSLYUC		.10000	SASSLYDC		.01000
DASSLYNB	ENTRPREN	-	92.20000			
DASSLYXB	SASSMLYB	-	79.00000	SASSLYXB		1.00000
DASSLYXB	SASSLYZB	-	1.00000	ENTRPREN	-	18.60000
DASSLYZB	SASSMLYB	-	27.00000	SASSLYZB		1.00000
DASSLYZB	ENTRPREN	-	8.40000			
DASSLYSB	SASSMLYB	-	449.00000	ENTRPREN	-	355.40000
DHTRTTUB	SHTRTTCB		1.00000	SHTRTTUB	-	1.00000
DHTRTTUB	ENTRPREN	-	35.00000			
DWELDGUB	SWELDGCB		1.00000	SWELDGUB	-	1.00000
DWELDGUB	ENTRPREN	-	35.00000			
DASSLYUB	SASSLYCB		1.00000	SASSLYUB	-	1.00000

INPUT LISTING

FACTORY STRIKE IN MARCH

DASSLYUB	ENTRPREN	-	110.00000			
DHTRTTDB	SHTRTTCB	-	1.00000	SHTRTTDB	-	1.00000
DHTRTTDB	ENTRPREN	-	5.00000			
DWELDGDB	SWELDGCB	-	1.00000	SWELDGDB	-	1.00000
DWELDGDB	ENTRPREN	-	5.00000			
DASSLYDB	SASSLYCB	-	1.00000	SASSLYDB	-	1.00000
DASSLYDB	ENTRPREN	-	5.00000			
PFWDTRPC	SHTRTMTC		50.56000	SWELDNGC		152.70000
PFWDTRPC	SASSMLYC		97.13000	SFWDTMSC		1.00000
PFWDTRPC	ENTRPREN	-	2340.12000			
PTRALRPC	SHTRTMTC		19.36000	SWELDNGC		49.60000
PTRALRPC	SASSMLYC		67.17000	SHYDRAMC		1.00000
PTRALRPC	SHYDRAMD		1.00000	SHYDRAME		1.00000
PTRALRPC	SHYDRAMF		1.00000	SHYDRAMG		1.00000
PTRALRPC	SHYDRAMH		1.00000	SHYDRAMI		1.00000
PTRALRPC	SHYDRAMJ		1.00000	SHYDRAMK		1.00000
PTRALRPC	SHYDRAML		1.00000	SHYDRAMM		1.00000
PTRALRPC	STRALMSC		1.00000	ENTRPREN	-	184.65000
PLOADRPC	SHTRTMTC		13.36000	SWELDNGC		86.51000
PLOADRPC	SASSMLYC		14.91000	SHYDRAMC		1.00000
PLOADRPC	SHYDRAMD		1.00000	SHYDRAME		1.00000
PLOADRPC	SHYDRAMF		1.00000	SHYDRAMG		1.00000
PLOADRPC	SHYDRAMH		1.00000	SHYDRAMI		1.00000
PLOADRPC	SHYDRAMJ		1.00000	SHYDRAMK		1.00000
PLOADRPC	SHYDRAML		1.00000	SHYDRAMM		1.00000
PLOADRPC	SLOADMSC		1.00000	ENTRPREN	-	188.97000
PDIGGRPC	SHTRTMTC		24.43000	SWELDNGC		147.91000
PDIGGRPC	SASSMLYC		54.10000	SDIGGMSC		1.00000
PDIGGRPC	ENTRPREN	-	598.39000			
MFWDTRPC	SFWDTMSC	-	1.00000	SFWDTPSC		1.00000
MFWDTRPC	ENTRPREN		3809.00000			
MTRALRPC	STRALMSC	-	1.00000	STRALPSC		1.00000
MTRALRPC	ENTRPREN		361.10000			
MLOADRPC	SLOADMSC	-	1.00000	SLOADPSC		1.00000
MLOADRPC	ENTRPREN		409.75000			
MDIGGRPC	SDIGGMSC	-	1.00000	SDIGGPSC		1.00000
MDIGGRPC	ENTRPREN		1187.40000			
PFWDTRIC	SFWDTMSC	-	1.00000	SFWDTMSD		1.00000
PFWDTRIC	ENTRPREN	-	36.80000			
PTRALRIC	STRALMSC	-	1.00000	STRALMSD		1.00000
PTRALRIC	ENTRPREN	-	3.20000			
PLOADRIC	SLOADMSC	-	1.00000	SLOADMSD		1.00000
PLOADRIC	ENTRPREN	-	3.20000			
PDIGGRIC	SDIGGMSC	-	1.00000	SDIGGMSD		1.00000
PDIGGRIC	ENTRPREN	-	9.80000			
DHTRTTNC	SHTRTMTC	-	331.00000	SHTRTTXC	-	1.00000
DHTRTTNC	SHTRTTCC	-	1.00000	SHTRTTCD		1.00000
DHTRTTNC	SHTRTTUD		.11000	SHTRTTDD		.01000
DHTRTTNC	ENTRPREN	-	82.40000			
DHTRTTXC	SHTRTMTC	-	58.00000	SHTRTTXC		1.00000
DHTRTTXC	SHTRTTZC	-	1.00000	ENTRPREN	-	16.80000
DHTRTTZC	SHTRTMTC	-	20.00000	SHTRTTZC		1.00000
DHTRTTZC	ENTRPREN	-	7.60000			
DHTRTTSC	SHTRTMTC	-	331.00000	ENTRPREN	-	274.00000

INPUT LISTING

FACTORY STRIKE IN MARCH

DWELDGNC	SWELDNGC	-	352.00000	SWELDGXC	-	1.00000
DWELDGNC	SWELDGCC	-	1.00000	SWELDGCD		1.00000
DWELDGNC	SWELDGUD		.07000	SWELDGDD		.02000
DWELDGNC	ENTRPREN	-	82.40000			
DWELDGXC	SWELDNGC	-	62.00000	SWELDGXC		1.00000
DWELDGXC	SWELDGZC	-	1.00000	ENTRPREN	-	16.80000
DWELDGZC	SWELDNGC	-	21.00000	SWELDGZC		1.00000
DWELDGZC	ENTRPREN	-	7.60000			
DWELDGSC	SWELDNGC	-	352.00000	ENTRPREN	-	287.00000
DASSLYNC	SASSMLYC	-	408.00000	SASSLYXC	-	1.00000
DASSLYNC	SASSLYCC	-	1.00000	SASSLYCD		1.00000
DASSLYNC	SASSLYUD		.10000	SASSLYDD		.01000
DASSLYNC	ENTRPREN	-	82.40000			
DASSLYXC	SASSMLYC	-	71.00000	SASSLYXC		1.00000
DASSLYXC	SASSLYZC	-	1.00000	ENTRPREN	-	16.80000
DASSLYZC	SASSMLYC	-	24.00000	SASSLYZC		1.00000
DASSLYZC	ENTRPREN	-	7.60000			
DASSLYSC	SASSMLYC	-	408.00000	ENTRPREN	-	323.00000
DHTRTTUC	SHTRTTCC		1.00000	SHTRTTUC	-	1.00000
DHTRTTUC	ENTRPREN	-	35.00000			
DWELDGUC	SWELDGCC		1.00000	SWELDGUC	-	1.00000
DWELDGUC	ENTRPREN	-	35.00000			
DASSLYUC	SASSLYCC		1.00000	SASSLYUC	-	1.00000
DASSLYUC	ENTRPREN	-	110.00000			
DHTRTTDC	SHTRTTCC	-	1.00000	SHTRTTDC	-	1.00000
DHTRTTDC	ENTRPREN	-	5.00000			
DWELDGDC	SWELDGCC	-	1.00000	SWELDGDC	-	1.00000
DWELDGDC	ENTRPREN	-	5.00000			
DASSLYDC	SASSLYCC	-	1.00000	SASSLYDC	-	1.00000
DASSLYDC	ENTRPREN	-	5.00000			
PFWDTRPD	SHTRTMTD		50.56000	SWELDNGD		152.70000
PFWDTRPD	SASSMLYD		97.13000	SFWDTMSD		1.00000
PFWDTRPD	ENTRPREN	-	2340.12000			
PTRALRPD	SHTRTMTD		19.36000	SWELDNGD		49.60000
PTRALRPD	SASSMLYD		67.17000	SHYDRAMD		1.00000
PTRALRPD	SHYDRAME		1.00000	SHYDRAMF		1.00000
PTRALRPD	SHYDRAMG		1.00000	SHYDRAMH		1.00000
PTRALRPD	SHYDRAMI		1.00000	SHYDRAMJ		1.00000
PTRALRPD	SHYDRAMK		1.00000	SHYDRAML		1.00000
PTRALRPD	SHYDRAMM		1.00000	STRALMSD		1.00000
PTRALRPD	ENTRPREN	-	184.65000			
PLOADRPD	SHTRTMTD		13.36000	SWELDNGD		86.51000
PLOADRPD	SASSMLYD		14.91000	SHYDRAMD		1.00000
PLOADRPD	SHYDRAME		1.00000	SHYDRAMF		1.00000
PLOADRPD	SHYDRAMG		1.00000	SHYDRAMH		1.00000
PLOADRPD	SHYDRAMI		1.00000	SHYDRAMJ		1.00000
PLOADRPD	SHYDRAMK		1.00000	SHYDRAML		1.00000
PLOADRPD	SHYDRAMM		1.00000	SLOADMSD		1.00000
PLOADRPD	ENTRPREN	-	188.97000			
PDIGGRPD	SHTRTMTD		24.43000	SWELDNGD		147.91000
PDIGGRPD	SASSMLYD		54.10000	SDIGGMSD		1.00000
PDIGGRPD	ENTRPREN	-	598.39000			
MFWDTRPD	SFWDTMSD	-	1.00000	SFWDTPSD		1.00000
MFWDTRPD	ENTRPREN		3809.00000			

FACTORY STRIKE IN MARCH

MTRALRPD	STRALMSD	-	1.00000	STRALPSD		1.00000
MTRALRPD	ENTRPREN		361.10000			
MLOADRPD	SLOADMSD	-	1.00000	SLOADPSD		1.00000
MLOADRPD	ENTRPREN		409.75000			
MDIGGRPD	SDIGGMSD	-	1.00000	SDIGGPSD		1.00000
MDIGGRPD	ENTRPREN		1187.40000			
PFWDTRID	SFWDTMSD	-	1.00000	SFWDTMSE		1.00000
PFWDTRID	ENTRPREN	-	36.80000			
PTRALRID	STRALMSD	-	1.00000	STRALMSE		1.00000
PTRALRID	ENTRPREN	-	3.20000			
PLOADRID	SLOADMSD	-	1.00000	SLOADMSE		1.00000
PLOADRID	ENTRPREN	-	3.20000			
PDIGGRID	SDIGGMSD	-	1.00000	SDIGGMSE		1.00000
PDIGGRID	ENTRPREN	-	9.80000			
DHTRTTND	SHTRTMTD	-	331.00000	SHTRTTXD	-	1.00000
DHTRTTND	SHTRTTCD	-	1.00000	SHTRTTCE		1.00000
DHTRTTND	SHTRTTUE		.11000	SHTRTTDE		.01000
DHTRTTND	ENTRPREN	-	82.40000			
DHTRTTXD	SHTRTMTD	-	58.00000	SHTRTTXD		1.00000
DHTRTTXD	SHTRTTZD	-	1.00000	ENTRPREN	-	16.80000
DHTRTTZD	SHTRTMTD	-	20.00000	SHTRTTZD		1.00000
DHTRTTZD	ENTRPREN	-	7.60000			
DHTRTTSD	SHTRTMTD	-	331.00000	ENTRPREN	-	274.00000
DWELDGND	SWELDNGD	-	352.00000	SWELDGXD	-	1.00000
DWELDGND	SWELDGCD	-	1.00000	SWELDGCE		1.00000
DWELDGND	SWELDGUE		.07000	SWELDGDE		.02000
DWELDGND	ENTRPREN	-	82.40000			
DWELDGXD	SWELDNGD	-	62.00000	SWELDGXD		1.00000
DWELDGXD	SWELDGZD	-	1.00000	ENTRPREN	-	16.80000
DWELDGZD	SWELDNGD	-	21.00000	SWELDGZD		1.00000
DWELDGZD	ENTRPREN	-	7.60000			
DWELDGSD	SWELDNGD	-	352.00000	ENTRPREN	-	287.00000
DASSLYND	SASSMLYD	-	408.00000	SASSLYXD	-	1.00000
DASSLYND	SASSLYCD	-	1.00000	SASSLYCE		1.00000
DASSLYND	SASSLYUE		.10000	SASSLYDE		.01000
DASSLYND	ENTRPREN	-	82.40000			
DASSLYXD	SASSMLYD	-	71.00000	SASSLYXD		1.00000
DASSLYXD	SASSLYZD	-	1.00000	ENTRPREN	-	16.80000
DASSLYZD	SASSMLYD	-	24.00000	SASSLYZD		1.00000
DASSLYZD	ENTRPREN	-	7.60000			
DASSLYSD	SASSMLYD	-	408.00000	ENTRPREN	-	323.00000
DHTRTTUD	SHTRTTCD		1.00000	SHTRTTUD	-	1.00000
DHTRTTUD	ENTRPREN	-	35.00000			
DWELDGUD	SWELDGCD		1.00000	SWELDGUD	-	1.00000
DWELDGUD	ENTRPREN	-	35.00000			
DASSLYUD	SASSLYCD		1.00000	SASSLYUD	-	1.00000
DASSLYUD	ENTRPREN	-	110.00000			
DHTRTTDD	SHTRTTCD	-	1.00000	SHTRTTDD	-	1.00000
DHTRTTDD	ENTRPREN	-	5.00000			
DWELDGDD	SWELDGCD	-	1.00000	SWELDGDD	-	1.00000
DWELDGDD	ENTRPREN	-	5.00000			
DASSLYDD	SASSLYCD	-	1.00000	SASSLYDD	-	1.00000
DASSLYDD	ENTRPREN	-	5.00000			
PFWDTRPE	SHTRTMTE		50.56000	SWELDNGE		152.70000

INPUT LISTING

FACTORY STRIKE IN MARCH

PFWDTRPE	SASSMLYE	97.13000	SFWDTMSE	1.00000
PFWDTRPE	ENTRPREN	-2340.12000		
PTRALRPE	SHTRTMTE	19.36000	SWELDNGE	49.60000
PTRALRPE	SASSMLYE	67.17000	SHYDRAME	1.00000
PTRALRPE	SHYDRAMF	1.00000	SHYDRAMG	1.00000
PTRALRPE	SHYDRAMH	1.00000	SHYDRAMI	1.00000
PTRALRPE	SHYDRAMJ	1.00000	SHYDRAMK	1.00000
PTRALRPE	SHYDRAML	1.00000	SHYDRAMM	1.00000
PTRALRPE	STRALMSE	1.00000	ENTRPREN	-184.65000
PLOADRPE	SHTRTMTE	13.36000	SWELDNGE	86.51000
PLOADRPE	SASSMLYE	14.91000	SHYDRAME	1.00000
PLOADRPE	SHYDRAMF	1.00000	SHYDRAMG	1.00000
PLOADRPE	SHYDRAMH	1.00000	SHYDRAMI	1.00000
PLOADRPE	SHYDRAMJ	1.00000	SHYDRAMK	1.00000
PLOADRPE	SHYDRAML	1.00000	SHYDRAMM	1.00000
PLOADRPE	SLOADMSE	1.00000	ENTRPREN	-188.97000
PDIGGRPE	SHTRTMTE	24.43000	SWELDNGE	147.91000
PDIGGRPE	SASSMLYE	54.10000	SDIGGMSE	1.00000
PDIGGRPE	ENTRPREN	-598.39000		
MFWDTRPE	SFWDTMSE	-1.00000	SFWDTPSE	1.00000
MFWDTRPE	ENTRPREN	3809.00000		
MTRALRPE	STRALMSE	-1.00000	STRALPSE	1.00000
MTRALRPE	ENTRPREN	361.10000		
MLOADRPE	SLOADMSE	-1.00000	SLOADPSE	1.00000
MLOADRPE	ENTRPREN	409.75000		
MDIGGRPE	SDIGGMSE	-1.00000	SDIGGPSE	1.00000
MDIGGRPE	ENTRPREN	1187.40000		
PFWDTRIE	SFWDTMSE	-1.00000	SFWDTMSF	1.00000
PFWDTRIE	ENTRPREN	-45.90000		
PTRALRIE	STRALMSE	-1.00000	STRALMSF	1.00000
PTRALRIE	ENTRPREN	-4.00000		
PLOADRIE	SLOADMSE	-1.00000	SLOADMSF	1.00000
PLOADRIE	ENTRPREN	-4.00000		
PDIGGRIE	SDIGGMSE	-1.00000	SDIGGMSF	1.00000
PDIGGRIE	ENTRPREN	-12.20000		
DHTRTTNE	SHTRTMTE	-397.00000	SHTRTTXE	-1.00000
DHTRTTNE	SHTRTTCE	-1.00000	SHTRTTCF	1.00000
DHTRTTNE	SHTRTTUF	.11000	SHTRTTDF	.01000
DHTRTTNE	ENTRPREN	-99.40000		
DHTRTTXE	SHTRTMTE	-69.00000	SHTRTTXE	1.00000
DHTRTTXE	SHTRTTZE	-1.00000	ENTRPREN	-20.40000
DHTRTTZE	SHTRTMTE	-24.00000	SHTRTTZE	1.00000
DHTRTTZE	ENTRPREN	-9.20000		
DHTRTTSE	SHTRTMTE	-397.00000	ENTRPREN	-328.80000
DWELDGNE	SWELDNGE	-422.00000	SWELDGXE	-1.00000
DWELDGNE	SWELDGCE	-1.00000	SWELDGCF	1.00000
DWELDGNE	SWELDGUF	.07000	SWELDGDF	.02000
DWELDGNE	ENTRPREN	-99.40000		
DWELDGXE	SWELDNGE	-74.00000	SWELDGXE	1.00000
DWELDGXE	SWELDGZE	-1.00000	ENTRPREN	-20.40000
DWELDGZE	SWELDNGE	-25.00000	SWELDGZE	1.00000
DWELDGZE	ENTRPREN	-9.20000		
DWELDGSE	SWELDNGE	-422.00000	ENTRPREN	-343.80000
DASSLYNE	SASSMLYE	-490.00000	SASSLYXE	-1.00000

INPUT LISTING

FACTORY STRIKE IN MARCH

DASSLYNE	SASSLYCE	-	1.00000	SASSLYCF		1.00000
DASSLYNE	SASSLYUF		.10000	SASSLYDF		.01000
DASSLYNE	ENTRPREN	-	99.40000			
DASSLYXE	SASSMLYE	-	86.00000	SASSLYXE		1.00000
DASSLYXE	SASSLYZE	-	1.00000	ENTRPREN	-	20.40000
DASSLYZE	SASSMLYE	-	29.00000	SASSLYZE		1.00000
DASSLYZE	ENTRPREN	-	9.20000			
DASSLYSE	SASSMLYE	-	490.00000	ENTRPREN	-	387.80000
DHTRTTUE	SHTRTTCE		1.00000	SHTRTTUE	-	1.00000
DHTRTTUE	ENTRPREN	-	35.00000			
DWELDGUE	SWELDGCE		1.00000	SWELDGUE	-	1.00000
DWELDGUE	ENTRPREN	-	35.00000			
DASSLYUE	SASSLYCE		1.00000	SASSLYUE	-	1.00000
DASSLYUE	ENTRPREN	-	110.00000			
DHTRTTDE	SHTRTTCE	-	1.00000	SHTRTTDE	-	1.00000
DHTRTTDE	ENTRPREN	-	5.00000			
DWELDGDE	SWELDGCE	-	1.00000	SWELDGDE	-	1.00000
DWELDGDE	ENTRPREN	-	5.00000			
DASSLYDE	SASSLYCE	-	1.00000	SASSLYDE	-	1.00000
DASSLYDE	ENTRPREN	-	5.00000			
PFWDTRPF	SHTRTMTF		50.56000	SWELDNGF		152.70000
PFWDTRPF	SASSMLYF		97.13000	SFWDTMSF		1.00000
PFWDTRPF	ENTRPREN	-	2340.12000			
PTRALRPF	SHTRTMTF		19.36000	SWELDNGF		49.60000
PTRALRPF	SASSMLYF		67.17000	SHYDRAMF		1.00000
PTRALRPF	SHYDRAMG		1.00000	SHYDRAMH		1.00000
PTRALRPF	SHYDRAMI		1.00000	SHYDRAMJ		1.00000
PTRALRPF	SHYDRAMK		1.00000	SHYDRAML		1.00000
PTRALRPF	SHYDRAMM		1.00000	STRALMSF		1.00000
PTRALRPF	ENTRPREN	-	184.65000			
PLOADRPF	SHTRTMTF		13.36000	SWELDNGF		86.51000
PLOADRPF	SASSMLYF		14.91000	SHYDRAMF		1.00000
PLOADRPF	SHYDRAMG		1.00000	SHYDRAMH		1.00000
PLOADRPF	SHYDRAMI		1.00000	SHYDRAMJ		1.00000
PLOADRPF	SHYDRAMK		1.00000	SHYDRAML		1.00000
PLOADRPF	SHYDRAMM		1.00000	SLOADMSF		1.00000
PLOADRPF	ENTRPREN	-	188.97000			
PDIGGRPF	SHTRTMTF		24.43000	SWELDNGF		147.91000
PDIGGRPF	SASSMLYF		54.10000	SDIGGMSF		1.00000
PDIGGRPF	ENTRPREN	-	598.39000			
MFWDTRPF	SFWDTMSF	-	1.00000	SFWDTPSF		1.00000
MFWDTRPF	ENTRPREN		3809.00000			
MTRALRPF	STRALMSF	-	1.00000	STRALPSF		1.00000
MTRALRPF	ENTRPREN		361.10000			
MLOADRPF	SLOADMSF	-	1.00000	SLOADPSF		1.00000
MLOADRPF	ENTRPREN		409.75000			
MDIGGRPF	SDIGGMSF	-	1.00000	SDIGGPSF		1.00000
MDIGGRPF	ENTRPREN		1187.40000			
PFWDTRIF	SFWDTMSF	-	1.00000	SFWDTMSG		1.00000
PFWDTRIF	ENTRPREN	-	36.80000			
PTRALRIF	STRALMSF	-	1.00000	STRALMSG		1.00000
PTRALRIF	ENTRPREN	-	3.20000			
PLOADRIF	SLOADMSF	-	1.00000	SLOADMSG		1.00000
PLOADRIF	ENTRPREN	-	3.20000			

INPUT LISTING

FACTORY STRIKE IN MARCH

PDIGGRIF	SDIGGMSF	-	1.00000	SDIGGMSG		1.00000
PDIGGRIF	ENTRPREN	-	9.80000			
DHTRTTNF	SHTRTMTF	-	315.00000	SHTRTTXF	-	1.00000
DHTRTTNF	SHTRTTCF	-	1.00000	SHTRTTCG		1.00000
DHTRTTNF	SHTRTTUG		.11000	SHTRTTDG		.01000
DHTRTTNF	ENTRPREN	-	78.80000			
DHTRTTXF	SHTRTMTF	-	55.00000	SHTRTTXF		1.00000
DHTRTTXF	SHTRTTZF	-	1.00000	ENTRPREN	-	16.20000
DHTRTTZF	SHTRTMTF	-	19.00000	SHTRTTZF		1.00000
DHTRTTZF	ENTRPREN	-	7.20000			
DHTRTTSF	SHTRTMTF	-	315.00000	ENTRPREN	-	260.80000
DWELDGNF	SWELDNGF	-	334.00000	SWELDGXF	-	1.00000
DWELDGNF	SWELDGCF	-	1.00000	SWELDGCG		1.00000
DWELDGNF	SWELDGUG		.07000	SWELDGDG		.02000
DWELDGNF	ENTRPREN	-	78.80000			
DWELDGXF	SWELDNGF	-	58.00000	SWELDGXF		1.00000
DWELDGXF	SWELDGZF	-	1.00000	ENTRPREN	-	16.20000
DWELDGZF	SWELDNGF	-	20.00000	SWELDGZF		1.00000
DWELDGZF	ENTRPREN	-	7.20000			
DWELDGSF	SWELDNGF	-	334.00000	ENTRPREN	-	272.80000
DASSLYNF	SASSMLYF	-	388.00000	SASSLYXF	-	1.00000
DASSLYNF	SASSLYCF	-	1.00000	SASSLYCG		1.00000
DASSLYNF	SASSLYUG		.10000	SASSLYDG		.01000
DASSLYNF	ENTRPREN	-	78.80000			
DASSLYXF	SASSMLYF	-	68.00000	SASSLYXF		1.00000
DASSLYXF	SASSLYZF	-	1.00000	ENTRPREN	-	16.20000
DASSLYZF	SASSMLYF	-	23.00000	SASSLYZF		1.00000
DASSLYZF	ENTRPREN	-	7.20000			
DASSLYSF	SASSMLYF	-	388.00000	ENTRPREN	-	306.80000
DHTRTTUF	SHTRTTCF		1.00000	SHTRTTUF	-	1.00000
DHTRTTUF	ENTRPREN	-	35.00000			
DWELDGUF	SWELDGCF		1.00000	SWELDGUF	-	1.00000
DWELDGUF	ENTRPREN	-	35.00000			
DASSLYUF	SASSLYCF		1.00000	SASSLYUF	-	1.00000
DASSLYUF	ENTRPREN	-	110.00000			
DHTRTTDF	SHTRTTCF	-	1.00000	SHTRTTDF	-	1.00000
DHTRTTDF	ENTRPREN	-	5.00000			
DWELDGDF	SWELDGCF	-	1.00000	SWELDGDF	-	1.00000
DWELDGDF	ENTRPREN	-	5.00000			
DASSLYDF	SASSLYCF	-	1.00000	SASSLYDF	-	1.00000
DASSLYDF	ENTRPREN	-	5.00000			
PFWDTRPG	SHTRTMTG		50.56000	SWELDNGG		152.70000
PFWDTRPG	SASSMLYG		97.13000	SFWDTMSG		1.00000
PFWDTRPG	ENTRPREN	-	2340.12000			
PTRALRPG	SHTRTMTG		19.36000	SWELDNGG		49.60000
PTRALRPG	SASSMLYG		67.17000	SHYDRAMG		1.00000
PTRALRPG	SHYDRAMH		1.00000	SHYDRAMI		1.00000
PTRALRPG	SHYDRAMJ		1.00000	SHYDRAMK		1.00000
PTRALRPG	SHYDRAML		1.00000	SHYDRAMM		1.00000
PTRALRPG	STRALMSG		1.00000	ENTRPREN	-	184.65000
PLOADRPG	SHTRTMTG		13.36000	SWELDNGG		86.51000
PLOADRPG	SASSMLYG		14.91000	SHYDRAMG		1.00000
PLOADRPG	SHYDRAMH		1.00000	SHYDRAMI		1.00000
PLOADRPG	SHYDRAMJ		1.00000	SHYDRAMK		1.00000

INPUT LISTING

FACTORY STRIKE IN MARCH

PLOADRPG	SHYDRAML		1.00000	SHYDRAMM		1.00000
PLOADRPG	SLOADMSG		1.00000	ENTRPREN	-	188.97000
PDIGGRPG	SHTRTMTG		24.43000	SWELDNGG		147.91000
PDIGGRPG	SASSMLYG		54.10000	SDIGGMSG		1.00000
PDIGGRPG	ENTRPREN	-	598.39000			
MFWDTRPG	SFWDTMSG	-	1.00000	SFWDTPSG		1.00000
MFWDTRPG	ENTRPREN		3809.00000			
MTRALRPG	STRALMSG	-	1.00000	STRALPSG		1.00000
MTRALRPG	ENTRPREN		361.10000			
MLOADRPG	SLOADMSG	-	1.00000	SLOADPSG		1.00000
MLOADRPG	ENTRPREN		409.75000			
MDIGGRPG	SDIGGMSG	-	1.00000	SDIGGPSG		1.00000
MDIGGRPG	ENTRPREN		1187.40000			
PFWDTRIG	SFWDTMSG	-	1.00000	SFWDTMSH		1.00000
PFWDTRIG	ENTRPREN	-	36.80000			
PTRALRIG	STRALMSG	-	1.00000	STRALMSH		1.00000
PTRALRIG	ENTRPREN	-	3.20000			
PLOADRIG	SLOADMSG	-	1.00000	SLOADMSH		1.00000
PLOADRIG	ENTRPREN	-	3.20000			
PDIGGRIG	SDIGGMSG	-	1.00000	SDIGGMSH		1.00000
PDIGGRIG	ENTRPREN	-	9.80000			
DHTRTTNG	SHTRTMTG	-	331.00000	SHTRTTXG	-	1.00000
DHTRTTNG	SHTRTTCG	-	1.00000	SHTRTTCH		1.00000
DHTRTTNG	SHTRTTUH		.11000	SHTRTTDH		.01000
DHTRTTNG	ENTRPREN	-	82.40000			
DHTRTTXG	SHTRTMTG	-	58.00000	SHTRTTXG		1.00000
DHTRTTXG	SHTRTTZG	-	1.00000	ENTRPREN	-	16.80000
DHTRTTZG	SHTRTMTG	-	20.00000	SHTRTTZG		1.00000
DHTRTTZG	ENTRPREN	-	7.60000			
DHTRTTSG	SHTRTMTG	-	331.00000	ENTRPREN	-	274.00000
DWELDGNG	SWELDNGG	-	352.00000	SWELDGXG	-	1.00000
DWELDGNG	SWELDGCG	-	1.00000	SWELDGCH		1.00000
DWELDGNG	SWELDGUH		.07000	SWELDGDH		.02000
DWELDGNG	ENTRPREN	-	82.40000			
DWELDGXG	SWELDNGG	-	62.00000	SWELDGXG		1.00000
DWELDGXG	SWELDGZG	-	1.00000	ENTRPREN	-	16.80000
DWELDGZG	SWELDNGG	-	21.00000	SWELDGZG		1.00000
DWELDGZG	ENTRPREN	-	7.60000			
DWELDGSG	SWELDNGG	-	352.00000	ENTRPREN	-	287.00000
DASSLYNG	SASSMLYG	-	408.00000	SASSLYXG	-	1.00000
DASSLYNG	SASSLYCG	-	1.00000	SASSLYCH		1.00000
DASSLYNG	SASSLYUH		.10000	SASSLYDH		.01000
DASSLYNG	ENTRPREN	-	82.40000			
DASSLYXG	SASSMLYG	-	71.00000	SASSLYXG		1.00000
DASSLYXG	SASSLYZG	-	1.00000	ENTRPREN	-	16.80000
DASSLYZG	SASSMLYG	-	24.00000	SASSLYZG		1.00000
DASSLYZG	ENTRPREN	-	7.60000			
DASSLYSG	SASSMLYG	-	408.00000	ENTRPREN	-	323.00000
DHTRTTUG	SHTRTTCG		1.00000	SHTRTTUG	-	1.00000
DHTRTTUG	ENTRPREN	-	35.00000			
DWELDGUG	SWELDGCG		1.00000	SWELDGUG	-	1.00000
DWELDGUG	ENTRPREN	-	35.00000			
DASSLYUG	SASSLYCG		1.00000	SASSLYUG	-	1.00000
DASSLYUG	ENTRPREN	-	110.00000			

INPUT LISTING

FACTORY STRIKE IN MARCH

DHTRTTDG	SHTRTTCG	-	1.00000	SHTRTTDG	-	1.00000
DHTRTTDG	ENTRPREN	-	5.00000			
DWELDGDG	SWELDGCG	-	1.00000	SWELDGDG	-	1.00000
DWELDGDG	ENTRPREN	-	5.00000			
DASSLYDG	SASSLYCG	-	1.00000	SASSLYDG	-	1.00000
DASSLYDG	ENTRPREN	-	5.00000			
PFWDTRPH	SHTRTMTH		50.56000	SWELDNGH		152.70000
PFWDTRPH	SASSMLYH		97.13000	SFWDTMSH		1.00000
PFWDTRPH	ENTRPREN	-	2340.12000			
PTRALRPH	SHTRTMTH		19.36000	SWELDNGH		49.60000
PTRALRPH	SASSMLYH		67.17000	SHYDRAMH		1.00000
PTRALRPH	SHYDRAMI		1.00000	SHYDRAMJ		1.00000
PTRALRPH	SHYDRAMK		1.00000	SHYDRAML		1.00000
PTRALRPH	SHYDRAMM		1.00000	STRALMSH		1.00000
PTRALRPH	ENTRPREN	-	184.65000			
PLOADRPH	SHTRTMTH		13.36000	SWELDNGH		86.51000
PLOADRPH	SASSMLYH		14.91000	SHYDRAMH		1.00000
PLOADRPH	SHYDRAMI		1.00000	SHYDRAMJ		1.00000
PLOADRPH	SHYDRAMK		1.00000	SHYDRAML		1.00000
PLOADRPH	SHYDRAMM		1.00000	SLOADMSH		1.00000
PLOADRPH	ENTRPREN	-	188.97000			
PDIGGRPH	SHTRTMTH		24.43000	SWELDNGH		147.91000
PDIGGRPH	SASSMLYH		54.10000	SDIGGMSH		1.00000
PDIGGRPH	ENTRPREN	-	598.39000			
MFWDTRPH	SFWDTMSH	-	1.00000	SFWDTPSH		1.00000
MFWDTRPH	ENTRPREN		3809.00000			
MTRALRPH	STRALMSH	-	1.00000	STRALPSH		1.00000
MTRALRPH	ENTRPREN		361.10000			
MLOADRPH	SLOADMSH	-	1.00000	SLOADPSH		1.00000
MLOADRPH	ENTRPREN		409.75000			
MDIGGRPH	SDIGGMSH	-	1.00000	SDIGGPSH		1.00000
MDIGGRPH	ENTRPREN		1187.40000			
PFWDTRIH	SFWDTMSH	-	1.00000	SFWDTMSI		1.00000
PFWDTRIH	ENTRPREN	-	45.90000			
PTRALRIH	STRALMSH	-	1.00000	STRALMSI		1.00000
PTRALRIH	ENTRPREN	-	4.00000			
PLOADRIH	SLOADMSH	-	1.00000	SLOADMSI		1.00000
PLOADRIH	ENTRPREN	-	4.00000			
PDIGGRIH	SDIGGMSH	-	1.00000	SDIGGMSI		1.00000
PDIGGRIH	ENTRPREN	-	12.20000			
DHTRTTNH	SHTRTMTH	-	331.00000	SHTRTTXH	-	1.00000
DHTRTTNH	SHTRTTCH	-	1.00000	SHTRTTCI		1.00000
DHTRTTNH	SHTRTTUI		.11000	SHTRTTDI		.01000
DHTRTTNH	ENTRPREN	-	104.80000			
DHTRTTXH	SHTRTMTH	-	58.00000	SHTRTTXH		1.00000
DHTRTTXH	SHTRTTZH	-	1.00000	ENTRPREN	-	16.80000
DHTRTTZH	SHTRTMTH	-	20.00000	SHTRTTZH		1.00000
DHTRTTZH	ENTRPREN	-	7.60000			
DHTRTTSH	SHTRTMTH	-	331.00000	ENTRPREN	-	274.00000
DWELDGNH	SWELDNGH	-	352.00000	SWELDGXH	-	1.00000
DWELDGNH	SWELDGCH	-	1.00000	SWELDGCI		1.00000
DWELDGNH	SWELDGUI		.07000	SWELDGDI		.02000
DWELDGNH	ENTRPREN	-	104.80000			
DWELDGXH	SWELDNGH	-	62.00000	SWELDGXH		1.00000

INPUT LISTING

FACTORY STRIKE IN MARCH

DWELDGXH	SWELDGZH	-	1.00000	ENTRPREN	-	16.80000
DWELDGZH	SWELDNGH	-	21.00000	SWELDGZH		1.00000
DWELDGZH	ENTRPREN	-	7.60000			
DWELDGSH	SWELDNGH	-	352.00000	ENTRPREN	-	287.00000
DASSLYNH	SASSMLYH	-	408.00000	SASSLYXH	-	1.00000
DASSLYNH	SASSLYCH	-	1.00000	SASSLYCI		1.00000
DASSLYNH	SASSLYUI		.10000	SASSLYDI		.01000
DASSLYNH	ENTRPREN	-	104.80000			
DASSLYXH	SASSMLYH	-	71.00000	SASSLYXH		1.00000
DASSLYXH	SASSLYZH	-	1.00000	ENTRPREN	-	16.80000
DASSLYZH	SASSMLYH	-	24.00000	SASSLYZH		1.00000
DASSLYZH	ENTRPREN	-	7.60000			
DASSLYSH	SASSMLYH	-	408.00000	ENTRPREN	-	323.00000
DHTRTTUH	SHTRTTCH		1.00000	SHTRTTUH	-	1.00000
DHTRTTUH	ENTRPREN	-	35.00000			
DWELDGUH	SWELDGCH		1.00000	SWELDGUH	-	1.00000
DWELDGUH	ENTRPREN	-	35.00000			
DASSLYUH	SASSLYCH		1.00000	SASSLYUH	-	1.00000
DASSLYUH	ENTRPREN	-	110.00000			
DHTRTTDH	SHTRTTCH	-	1.00000	SHTRTTDH	-	1.00000
DHTRTTDH	ENTRPREN	-	5.00000			
DWELDGDH	SWELDGCH	-	1.00000	SWELDGDH	-	1.00000
DWELDGDH	ENTRPREN	-	5.00000			
DASSLYDH	SASSLYCH	-	1.00000	SASSLYDH	-	1.00000
DASSLYDH	ENTRPREN	-	5.00000			
PFWDTRPI	SHTRTMTI		50.56000	SWELDNGI		152.70000
PFWDTRPI	SASSMLYI		97.13000	SFWDTMSI		1.00000
PFWDTRPI	ENTRPREN	-	2340.12000			
PTRALRPI	SHTRTMTI		19.36000	SWELDNGI		49.60000
PTRALRPI	SASSMLYI		67.17000	SHYDRAMI		1.00000
PTRALRPI	SHYDRAMJ		1.00000	SHYDRAMK		1.00000
PTRALRPI	SHYDRAML		1.00000	SHYDRAMM		1.00000
PTRALRPI	STRALMSI		1.00000	ENTRPREN	-	184.65000
PLOADRPI	SHTRTMTI		13.36000	SWELDNGI		86.51000
PLOADRPI	SASSMLYI		14.91000	SHYDRAMI		1.00000
PLOADRPI	SHYDRAMJ		1.00000	SHYDRAMK		1.00000
PLOADRPI	SHYDRAML		1.00000	SHYDRAMM		1.00000
PLOADRPI	SLOADMSI		1.00000	ENTRPREN	-	188.97000
PDIGGRPI	SHTRTMTI		24.43000	SWELDNGI		147.91000
PDIGGRPI	SASSMLYI		54.10000	SDIGGMSI		1.00000
PDIGGRPI	ENTRPREN	-	598.39000			
MFWDTRPI	SFWDTMSI	-	1.00000	SFWDTPSI		1.00000
MFWDTRPI	ENTRPREN		3809.00000			
MTRALRPI	STRALMSI	-	1.00000	STRALPSI		1.00000
MTRALRPI	ENTRPREN		361.10000			
MLOADRPI	SLOADMSI	-	1.00000	SLOADPSI		1.00000
MLOADRPI	ENTRPREN		409.75000			
MDIGGRPI	SDIGGMSI	-	1.00000	SDIGGPSI		1.00000
MDIGGRPI	ENTRPREN		1187.40000			
PFWDTRII	SFWDTMSI	-	1.00000	SFWDTMSJ		1.00000
PFWDTRII	ENTRPREN	-	36.80000			
PTRALRII	STRALMSI	-	1.00000	STRALMSJ		1.00000
PTRALRII	ENTRPREN	-	3.20000			
PLOADRII	SLOADMSI	-	1.00000	SLOADMSJ		1.00000

FACTORY STRIKE IN MARCH

PLOADRII	ENTRPREN	-	3.20000				
PDIGGRII	SDIGGMSI	-	1.00000	SDIGGMSJ			1.00000
PDIGGRII	ENTRPREN	-	9.80000				
DHTRTTNI	SHTRTMTI	-	248.00000	SHTRTTXI	-		1.00000
DHTRTTNI	SHTRTTCI	-	1.00000	SHTRTTCJ			1.00000
DHTRTTNI	SHTRTTUJ		.11000	SHTRTTDJ			.01000
DHTRTTNI	ENTRPREN	-	84.20000				
DHTRTTXI	SHTRTMTI	-	43.00000	SHTRTTXI			1.00000
DHTRTTXI	SHTRTTZI	-	1.00000	ENTRPREN	-		12.60000
DHTRTTZI	SHTRTMTI	-	15.00000	SHTRTTZI			1.00000
DHTRTTZI	ENTRPREN	-	5.80000				
DHTRTTSI	SHTRTMTI	-	248.00000	ENTRPREN	-		205.00000
DWELDGNI	SWELDNGI	-	264.00000	SWELDGXI	-		1.00000
DWELDGNI	SWELDGCI	-	1.00000	SWELDGCJ			1.00000
DWELDGNI	SWELDGUJ		.07000	SWELDGDJ			.02000
DWELDGNI	ENTRPREN	-	84.20000				
DWELDGXI	SWELDNGI	-	46.00000	SWELDGXI			1.00000
DWELDGXI	SWELDGZI	-	1.00000	ENTRPREN	-		12.60000
DWELDGZI	SWELDNGI	-	16.00000	SWELDGZI			1.00000
DWELDGZI	ENTRPREN	-	5.80000				
DWELDGSI	SWELDNGI	-	264.00000	ENTRPREN	-		215.00000
DASSLYNI	SASSMLYI	-	306.00000	SASSLYXI	-		1.00000
DASSLYNI	SASSLYCI	-	1.00000	SASSLYCJ			1.00000
DASSLYNI	SASSLYUJ		.10000	SASSLYDJ			.01000
DASSLYNI	ENTRPREN	-	84.20000				
DASSLYXI	SASSMLYI	-	54.00000	SASSLYXI			1.00000
DASSLYXI	SASSLYZI	-	1.00000	ENTRPREN	-		12.60000
DASSLYZI	SASSMLYI	-	18.00000	SASSLYZI			1.00000
DASSLYZI	ENTRPREN	-	5.80000				
DASSLYSI	SASSMLYI	-	306.00000	ENTRPREN	-		242.00000
DHTRTTUI	SHTRTTCI		1.00000	SHTRTTUI	-		1.00000
DHTRTTUI	ENTRPREN	-	35.00000				
DWELDGUI	SWELDGCI		1.00000	SWELDGUI	-		1.00000
DWELDGUI	ENTRPREN	-	35.00000				
DASSLYUI	SASSLYCI		1.00000	SASSLYUI	-		1.00000
DASSLYUI	ENTRPREN	-	110.00000				
DHTRTTDI	SHTRTTCI	-	1.00000	SHTRTTDI	-		1.00000
DHTRTTDI	ENTRPREN	-	5.00000				
DWELDGDI	SWELDGCI	-	1.00000	SWELDGDI	-		1.00000
DWELDGDI	ENTRPREN	-	5.00000				
DASSLYDI	SASSLYCI	-	1.00000	SASSLYDI	-		1.00000
DASSLYDI	ENTRPREN	-	5.00000				
PFWDTRPJ	SHTRTMTJ		50.56000	SWELDNGJ			152.70000
PFWDTRPJ	SASSMLYJ		97.13000	SFWDTMSJ			1.00000
PFWDTRPJ	ENTRPREN	-	2340.12000				
PTRALRPJ	SHTRTMTJ		19.36000	SWELDNGJ			49.60000
PTRALRPJ	SASSMLYJ		67.17000	SHYDRAMJ			1.00000
PTRALRPJ	SHYDRAMK		1.00000	SHYDRAML			1.00000
PTRALRPJ	SHYDRAMM		1.00000	STRALMSJ			1.00000
PTRALRPJ	ENTRPREN	-	184.65000				
PLOADRPJ	SHTRTMTJ		13.36000	SWELDNGJ			86.51000
PLOADRPJ	SASSMLYJ		14.91000	SHYDRAMJ			1.00000
PLOADRPJ	SHYDRAMK		1.00000	SHYDRAML			1.00000
PLOADRPJ	SHYDRAMM		1.00000	SLOADMSJ			1.00000

INPUT LISTING

FACTORY STRIKE IN MARCH

PLOADRPJ	ENTRPREN	-	188.97000			
PDIGGRPJ	SHTRTMTJ		24.43000	SWELDNGJ		147.91000
PDIGGRPJ	SASSMLYJ		54.10000	SDIGGMSJ		1.00000
PDIGGRPJ	ENTRPREN	-	598.39000			
MFWDTRPJ	SFWDTMSJ	-	1.00000	SFWDTPSJ		1.00000
MFWDTRPJ	ENTRPREN		3809.00000			
MTRALRPJ	STRALMSJ	-	1.00000	STRALPSJ		1.00000
MTRALRPJ	ENTRPREN		361.10000			
MLOADRPJ	SLOADMSJ	-	1.00000	SLOADPSJ		1.00000
MLOADRPJ	ENTRPREN		409.75000			
MDIGGRPJ	SDIGGMSJ	-	1.00000	SDIGGPSJ		1.00000
MDIGGRPJ	ENTRPREN		1187.40000			
PFWDTRIJ	SFWDTMSJ	-	1.00000	SFWDTMSK		1.00000
PFWDTRIJ	ENTRPREN	-	36.80000			
PTRALRIJ	STRALMSJ	-	1.00000	STRALMSK		1.00000
PTRALRIJ	ENTRPREN	-	3.20000			
PLOADRIJ	SLOADMSJ	-	1.00000	SLOADMSK		1.00000
PLOADRIJ	ENTRPREN	-	3.20000			
PDIGGRIJ	SDIGGMSJ	-	1.00000	SDIGGMSK		1.00000
PDIGGRIJ	ENTRPREN	-	9.80000			
DHTRTTNJ	SHTRTMTJ	-	248.00000	SHTRTTXJ	-	1.00000
DHTRTTNJ	SHTRTTCJ	-	1.00000	SHTRTTCK		1.00000
DHTRTTNJ	SHTRTTUK		.11000	SHTRTTDK		.01000
DHTRTTNJ	ENTRPREN	-	84.20000			
DHTRTTXJ	SHTRTMTJ	-	43.00000	SHTRTTXJ		1.00000
DHTRTTXJ	SHTRTTZJ	-	1.00000	ENTRPREN	-	12.60000
DHTRTTZJ	SHTRTMTJ	-	15.00000	SHTRTTZJ		1.00000
DHTRTTZJ	ENTRPREN	-	5.80000			
DHTRTTSJ	SHTRTMTJ	-	248.00000	ENTRPREN	-	205.00000
DWELDGNJ	SWELDNGJ	-	264.00000	SWELDGXJ	-	1.00000
DWELDGNJ	SWELDGCJ	-	1.00000	SWELDGCK		1.00000
DWELDGNJ	SWELDGUK		.07000	SWELDGDK		.02000
DWELDGNJ	ENTRPREN	-	84.20000			
DWELDGXJ	SWELDNGJ	-	46.00000	SWELDGXJ		1.00000
DWELDGXJ	SWELDGZJ	-	1.00000	ENTRPREN	-	12.60000
DWELDGZJ	SWELDNGJ	-	16.00000	SWELDGZJ		1.00000
DWELDGZJ	ENTRPREN	-	5.80000			
DWELDGSJ	SWELDNGJ	-	264.00000	ENTRPREN	-	215.00000
DASSLYNJ	SASSMLYJ	-	306.00000	SASSLYXJ	-	1.00000
DASSLYNJ	SASSLYCJ	-	1.00000	SASSLYCK		1.00000
DASSLYNJ	SASSLYUK		.10000	SASSLYDK		.01000
DASSLYNJ	ENTRPREN	-	84.20000			
DASSLYXJ	SASSMLYJ	-	54.00000	SASSLYXJ		1.00000
DASSLYXJ	SASSLYZJ	-	1.00000	ENTRPREN	-	12.60000
DASSLYZJ	SASSMLYJ	-	18.00000	SASSLYZJ		1.00000
DASSLYZJ	ENTRPREN	-	5.80000			
DASSLYSJ	SASSMLYJ	-	306.00000	ENTRPREN	-	242.00000
DHTRTTUJ	SHTRTTCJ		1.00000	SHTRTTUJ	-	1.00000
DHTRTTUJ	ENTRPREN	-	35.00000			
DWELDGUJ	SWELDGCJ		1.00000	SWELDGUJ	-	1.00000
DWELDGUJ	ENTRPREN	-	35.00000			
DASSLYUJ	SASSLYCJ		1.00000	SASSLYUJ	-	1.00000
DASSLYUJ	ENTRPREN	-	110.00000			
DHTRTTDJ	SHTRTTCJ	-	1.00000	SHTRTTDJ	-	1.00000

FACTORY STRIKE IN MARCH

DHTRTTDJ	ENTRPREN	-	5.00000			
DWELDGDJ	SWELDGCJ	-	1.00000	SWELDGDJ	-	1.00000
DWELDGDJ	ENTRPREN	-	5.00000			
DASSLYDJ	SASSLYCJ	-	1.00000	SASSLYDJ	-	1.00000
DASSLYDJ	ENTRPREN	-	5.00000			
PFWDTRPK	SHTRTMTK		50.56000	SWELDNGK		152.70000
PFWDTRPK	SASSMLYK		97.13000	SFWDTMSK		1.00000
PFWDTRPK	ENTRPREN	-	2340.12000			
PTRALRPK	SHTRTMTK		19.36000	SWELDNGK		49.60000
PTRALRPK	SASSMLYK		67.17000	SHYDRAMK		1.00000
PTRALRPK	SHYDRAML		1.00000	SHYDRAMM		1.00000
PTRALRPK	STRALMSK		1.00000	ENTRPREN	-	184.65000
PLOADRPK	SHTRTMTK		13.36000	SWELDNGK		86.51000
PLOADRPK	SASSMLYK		14.91000	SHYDRAMK		1.00000
PLOADRPK	SHYDRAML		1.00000	SHYDRAMM		1.00000
PLOADRPK	SLOADMSK		1.00000	ENTRPREN	-	188.97000
PDIGGRPK	SHTRTMTK		24.43000	SWELDNGK		147.91000
PDIGGRPK	SASSMLYK		54.10000	SDIGGMSK		1.00000
PDIGGRPK	ENTRPREN	-	598.39000			
MFWDTRPK	SFWDTMSK	-	1.00000	SFWDTPSK		1.00000
MFWDTRPK	ENTRPREN		3809.00000			
MTRALRPK	STRALMSK	-	1.00000	STRALPSK		1.00000
MTRALRPK	ENTRPREN		361.10000			
MLOADRPK	SLOADMSK	-	1.00000	SLOADPSK		1.00000
MLOADRPK	ENTRPREN		409.75000			
MDIGGRPK	SDIGGMSK	-	1.00000	SDIGGPSK		1.00000
MDIGGRPK	ENTRPREN		1187.40000			
PFWDTRIK	SFWDTMSK	-	1.00000	SFWDTMSL		1.00000
PFWDTRIK	ENTRPREN	-	45.90000			
PTRALRIK	STRALMSK	-	1.00000	STRALMSL		1.00000
PTRALRIK	ENTRPREN	-	4.00000			
PLOADRIK	SLOADMSK	-	1.00000	SLOADMSL		1.00000
PLOADRIK	ENTRPREN	-	4.00000			
PDIGGRIK	SDIGGMSK	-	1.00000	SDIGGMSL		1.00000
PDIGGRIK	ENTRPREN	-	12.20000			
DHTRTTNK	SHTRTMTK	-	395.00000	SHTRTTXK	-	1.00000
DHTRTTNK	SHTRTTCK	-	1.00000	SHTRTTCL		1.00000
DHTRTTNK	SHTRTTUL		.11000	SHTRTTDL		.01000
DHTRTTNK	ENTRPREN	-	99.00000			
DHTRTTXK	SHTRTMTK	-	69.00000	SHTRTTXK		1.00000
DHTRTTXK	SHTRTTZK	-	1.00000	ENTRPREN	-	19.80000
DHTRTTZK	SHTRTMTK	-	24.00000	SHTRTTZK		1.00000
DHTRTTZK	ENTRPREN	-	9.20000			
DHTRTTSK	SHTRTMTK	-	395.00000	ENTRPREN	-	326.40000
DWELDGNK	SWELDNGK	-	420.00000	SWELDGXK	-	1.00000
DWELDGNK	SWELDGCK	-	1.00000	SWELDGCL		1.00000
DWELDGNK	SWELDGUL		.07000	SWELDGDL		.02000
DWELDGNK	ENTRPREN	-	99.00000			
DWELDGXK	SWELDNGK	-	74.00000	SWELDGXK		1.00000
DWELDGXK	SWELDGZK	-	1.00000	ENTRPREN	-	19.80000
DWELDGZK	SWELDNGK	-	25.00000	SWELDGZK		1.00000
DWELDGZK	ENTRPREN	-	9.20000			
DWELDGSK	SWELDNGK	-	420.00000	ENTRPREN	-	342.40000
DASSLYNK	SASSMLYK	-	487.00000	SASSLYXK	-	1.00000

FACTORY STRIKE IN MARCH

DASSLYNK	SASSLYCK	-	1.00000	SASSLYCL		1.00000
DASSLYNK	SASSLYUL		.10000	SASSLYDL		.01000
DASSLYNK	ENTRPREN	-	99.00000			
DASSLYXK	SASSMLYK	-	85.00000	SASSLYXK		1.00000
DASSLYXK	SASSLYZK	-	1.00000	ENTRPREN	-	19.80000
DASSLYZK	SASSMLYK	-	29.00000	SASSLYZK		1.00000
DASSLYZK	ENTRPREN	-	9.20000			
DASSLYSK	SASSMLYK	-	487.00000	ENTRPREN	-	385.40000
DHTRTTUK	SHTRTTCK		1.00000	SHTRTTUK	-	1.00000
DHTRTTUK	ENTRPREN	-	35.00000			
DWELDGUK	SWELDGCK		1.00000	SWELDGUK	-	1.00000
DWELDGUK	ENTRPREN	-	35.00000			
DASSLYUK	SASSLYCK		1.00000	SASSLYUK	-	1.00000
DASSLYUK	ENTRPREN	-	110.00000			
DHTRTTDK	SHTRTTCK	-	1.00000	SHTRTTDK	-	1.00000
DHTRTTDK	ENTRPREN	-	5.00000			
DWELDGDK	SWELDGCK	-	1.00000	SWELDGDK	-	1.00000
DWELDGDK	ENTRPREN	-	5.00000			
DASSLYDK	SASSLYCK	-	1.00000	SASSLYDK	-	1.00000
DASSLYDK	ENTRPREN	-	5.00000			
PFWDTRPL	SHTRTMTL		50.56000	SWELDNGL		152.70000
PFWDTRPL	SASSMLYL		97.13000	SFWDTMSL		1.00000
PFWDTRPL	ENTRPREN	-	2340.12000			
PTRALRPL	SHTRTMTL		19.36000	SWELDNGL		49.60000
PTRALRPL	SASSMLYL		67.17000	SHYDRAML		1.00000
PTRALRPL	SHYDRAMM		1.00000	STRALMSL		1.00000
PTRALRPL	ENTRPREN	-	184.65000			
PLOADRPL	SHTRTMTL		13.36000	SWELDNGL		86.51000
PLOADRPL	SASSMLYL		14.91000	SHYDRAML		1.00000
PLOADRPL	SHYDRAMM		1.00000	SLOADMSL		1.00000
PLOADRPL	ENTRPREN	-	188.97000			
PDIGGRPL	SHTRTMTL		24.43000	SWELDNGL		147.91000
PDIGGRPL	SASSMLYL		54.10000	SDIGGMSL		1.00000
PDIGGRPL	ENTRPREN	-	598.39000			
MFWDTRPL	SFWDTMSL	-	1.00000	SFWDTPSL		1.00000
MFWDTRPL	ENTRPREN		3809.00000			
MTRALRPL	STRALMSL	-	1.00000	STRALPSL		1.00000
MTRALRPL	ENTRPREN		361.10000			
MLOADRPL	SLOADMSL	-	1.00000	SLOADPSL		1.00000
MLOADRPL	ENTRPREN		409.75000			
MDIGGRPL	SDIGGMSL	-	1.00000	SDIGGPSL		1.00000
MDIGGRPL	ENTRPREN		1187.40000			
PFWDTRIL	SFWDTMSL	-	1.00000	SFWDTMSM		1.00000
PFWDTRIL	ENTRPREN	-	36.80000			
PTRALRIL	STRALMSL	-	1.00000	STRALMSM		1.00000
PTRALRIL	ENTRPREN	-	3.20000			
PLOADRIL	SLOADMSL	-	1.00000	SLOADMSM		1.00000
PLOADRIL	ENTRPREN	-	3.20000			
PDIGGRIL	SDIGGMSL	-	1.00000	SDIGGMSM		1.00000
PDIGGRIL	ENTRPREN	-	9.80000			
DHTRTTNL	SHTRTMTL	-	331.00000	SHTRTTXL	-	1.00000
DHTRTTNL	SHTRTTCL	-	1.00000	SHTRTTCM		1.00000
DHTRTTNL	SHTRTTUM		.11000	SHTRTTDM		.01000
DHTRTTNL	ENTRPREN	-	82.40000			

INPUT LISTING

FACTORY STRIKE IN MARCH

DHTRTTXL	SHTRTMTL	-	58.00000	SHTRTTXL		1.00000
DHTRTTXL	SHTRTTZL	-	1.00000	ENTRPREN	-	16.80000
DHTRTTZL	SHTRTMTL	-	20.00000	SHTRTTZL		1.00000
DHTRTTZL	ENTRPREN	-	7.60000			
DHTRTTSL	SHTRTMTL	-	331.00000	ENTRPREN	-	274.00000
DWELDGNL	SWELDNGL	-	352.00000	SWELDGXL	-	1.00000
DWELDGNL	SWELDGCL	-	1.00000	SWELDGCM		1.00000
DWELDGNL	SWELDGUM		.07000	SWELDGDM		.02000
DWELDGNL	ENTRPREN	-	82.40000			
DWELDGXL	SWELDNGL	-	62.00000	SWELDGXL		1.00000
DWELDGXL	SWELDGZL	-	1.00000	ENTRPREN	-	16.80000
DWELDGZL	SWELDNGL	-	21.00000	SWELDGZL		1.00000
DWELDGZL	ENTRPREN	-	7.60000			
DWELDGSL	SWELDNGL	-	352.00000	ENTRPREN	-	287.00000
DASSLYNL	SASSMLYL	-	408.00000	SASSLYXL	-	1.00000
DASSLYNL	SASSLYCL	-	1.00000	SASSLYCM		1.00000
DASSLYNL	SASSLYUM		.10000	SASSLYDM		.01000
DASSLYNL	ENTRPREN	-	82.40000			
DASSLYXL	SASSMLYL	-	71.00000	SASSLYXL		1.00000
DASSLYXL	SASSLYZL	-	1.00000	ENTRPREN	-	16.80000
DASSLYZL	SASSMLYL	-	24.00000	SASSLYZL		1.00000
DASSLYZL	ENTRPREN	-	7.60000			
DASSLYSL	SASSMLYL	-	408.00000	ENTRPREN	-	323.00000
DHTRTTUL	SHTRTTCL		1.00000	SHTRTTUL	-	1.00000
DHTRTTUL	ENTRPREN	-	35.00000			
DWELDGUL	SWELDGCL		1.00000	SWELDGUL	-	1.00000
DWELDGUL	ENTRPREN	-	35.00000			
DASSLYUL	SASSLYCL		1.00000	SASSLYUL	-	1.00000
DASSLYUL	ENTRPREN	-	110.00000			
DHTRTTDL	SHTRTTCL	-	1.00000	SHTRTTDL	-	1.00000
DHTRTTDL	ENTRPREN	-	5.00000			
DWELDGDL	SWELDGCL	-	1.00000	SWELDGDL	-	1.00000
DWELDGDL	ENTRPREN	-	5.00000			
DASSLYDL	SASSLYCL	-	1.00000	SASSLYDL	-	1.00000
DASSLYDL	ENTRPREN	-	5.00000			
PFWDTRPM	SHTRTMTM		50.56000	SWELDNGM		152.70000
PFWDTRPM	SASSMLYM		97.13000	SFWDTMSM		1.00000
PFWDTRPM	ENTRPREN	-	2340.12000			
PTRALRPM	SHTRTMTM		19.36000	SWELDNGM		49.60000
PTRALRPM	SASSMLYM		67.17000	SHYDRAMM		1.00000
PTRALRPM	STRALMSM		1.00000	ENTRPREN	-	184.65000
PLOADRPM	SHTRTMTM		13.36000	SWELDNGM		86.51000
PLOADRPM	SASSMLYM		14.91000	SHYDRAMM		1.00000
PLOADRPM	SLOADMSM		1.00000	ENTRPREN	-	188.97000
PDIGGRPM	SHTRTMTM		24.43000	SWELDNGM		147.91000
PDIGGRPM	SASSMLYM		54.10000	SDIGGMSM		1.00000
PDIGGRPM	ENTRPREN	-	598.39000			
MFWDTRPM	SFWDTMSM	-	1.00000	SFWDTPSM		1.00000
MFWDTRPM	ENTRPREN		3809.00000			
MTRALRPM	STRALMSM	-	1.00000	STRALPSM		1.00000
MTRALRPM	ENTRPREN		361.10000			
MLOADRPM	SLOADMSM	-	1.00000	SLOADPSM		1.00000
MLOADRPM	ENTRPREN		409.75000			
MDIGGRPM	SDIGGMSM	-	1.00000	SDIGGPSM		1.00000

FACTORY STRIKE IN MARCH

MDIGGRPM	ENTRPREN		1187.40000			
PFWDTRIM	SFWDTMSM	-	1.00000	ENTRPREN	-	36.80000
PTRALRIM	STRALMSM	-	1.00000	ENTRPREN	-	3.20000
PLOADRIM	SLOADMSM	-	1.00000	ENTRPREN	-	3.20000
PDIGGRIM	SDIGGMSM	-	1.00000	ENTRPREN	-	9.80000
DHTRTTNM	SHTRTMTM	-	331.00000	SHTRTTXM	-	1.00000
DHTRTTNM	SHTRTTCM	-	1.00000	ENTRPREN	-	82.40000
DHTRTTXM	SHTRTMTM	-	58.00000	SHTRTTXM		1.00000
DHTRTTXM	SHTRTTZM	-	1.00000	ENTRPREN	-	16.80000
DHTRTTZM	SHTRTMTM	-	20.00000	SHTRTTZM		1.00000
DHTRTTZM	ENTRPREN	-	7.60000			
DHTRTTSM	SHTRTMTM	-	331.00000	ENTRPREN	-	274.00000
DWELDGNM	SWELDNGM	-	352.00000	SWELDGXM	-	1.00000
DWELDGNM	SWELDGCM	-	1.00000	ENTRPREN	-	82.40000
DWELDGXM	SWELDNGM	-	62.00000	SWELDGXM		1.00000
DWELDGXM	SWELDGZM	-	1.00000	ENTRPREN	-	16.80000
DWELDGZM	SWELDNGM	-	21.00000	SWELDGZM		1.00000
DWELDGZM	ENTRPREN	-	7.60000			
DWELDGSM	SWELDNGM	-	352.00000	ENTRPREN	-	287.00000
DASSLYNM	SASSMLYM	-	408.00000	SASSLYXM	-	1.00000
DASSLYNM	SASSLYCM	-	1.00000	ENTRPREN	-	82.40000
DASSLYXM	SASSMLYM	-	71.00000	SASSLYXM		1.00000
DASSLYXM	SASSLYZM	-	1.00000	ENTRPREN	-	16.80000
DASSLYZM	SASSMLYM	-	24.00000	SASSLYZM		1.00000
DASSLYZM	ENTRPREN	-	7.60000			
DASSLYSM	SASSMLYM	-	408.00000	ENTRPREN	-	323.00000
DHTRTTUM	SHTRTTCM		1.00000	SHTRTTUM	-	1.00000
DHTRTTUM	ENTRPREN	-	35.00000			
DWELDGUM	SWELDGCM		1.00000	SWELDGUM	-	1.00000
DWELDGUM	ENTRPREN	-	35.00000			
DASSLYUM	SASSLYCM		1.00000	SASSLYUM	-	1.00000
DASSLYUM	ENTRPREN	-	110.00000			
DHTRTTDM	SHTRTTCM	-	1.00000	SHTRTTDM	-	1.00000
DHTRTTDM	ENTRPREN	-	5.00000			
DWELDGDM	SWELDGCM	-	1.00000	SWELDGDM	-	1.00000
DWELDGDM	ENTRPREN	-	5.00000			
DASSLYDM	SASSLYCM	-	1.00000	SASSLYDM	-	1.00000
DASSLYDM	ENTRPREN	-	5.00000			

RHS

RHS1	SHYDRAMA	200.00000	SFWDTPSA	10.00000
RHS1	STRALPSA	100.00000	SLOADPSA	86.00000
RHS1	SDIGGPSA	235.00000	SHYDRAMB	420.00000
RHS1	SFWDTPSB	20.00000	STRALPSB	161.00000
RHS1	SLOADPSB	79.00000	SDIGGPSB	184.00000
RHS1	SHYDRAMC	620.00000	SFWDTPSC	35.00000
RHS1	STRALPSC	190.00000	SLOADPSC	117.00000
RHS1	SDIGGPSC	210.00000	SHYDRAMD	820.00000
RHS1	SFWDTPSD	40.00000	STRALPSD	190.00000
RHS1	SLOADPSD	118.00000	SDIGGPSD	237.00000
RHS1	SHYDRAME	1060.00000	SFWDTPSE	35.00000
RHS1	STRALPSE	108.00000	SLOADPSE	110.00000
RHS1	SDIGGPSE	259.00000	SHYDRAMF	1250.00000
RHS1	SFWDTPSF	65.00000	STRALPSF	22.00000
RHS1	SLOADPSF	135.00000	SDIGGPSF	235.00000

INPUT LISTING

FACTORY STRIKE IN MARCH

```
    RHS1         SHYDRAMG      1450.00000   SFWDTPSG       35.00000
    RHS1         STRALPSG         4.00000   SLOADPSG       89.00000
    RHS1         SDIGGPSG       208.00000   SHYDRAMH     1650.00000
    RHS1         SFWDTPSH        35.00000   STRALPSH       99.00000
    RHS1         SLOADPSH       110.00000   SDIGGPSH      201.00000
    RHS1         SHYDRAMI      1800.00000   SFWDTPSI       55.00000
    RHS1         STRALPSI       131.00000   SLOADPSI       99.00000
    RHS1         SDIGGPSI       181.00000   SHYDRAMJ     1950.00000
    RHS1         SFWDTPSJ        44.00000   STRALPSJ       85.00000
    RHS1         SLOADPSJ        74.00000   SDIGGPSJ      162.00000
    RHS1         SHYDRAMK      2190.00000   SFWDTPSK       38.00000
    RHS1         STRALPSK        50.00000   SLOADPSK       68.00000
    RHS1         SDIGGPSK       127.00000   SHYDRAML     2390.00000
    RHS1         SFWDTPSL        47.00000   SLOADPSL       85.00000
    RHS1         SDIGGPSL       158.00000   SHYDRAMM     2590.00000
    RHS1         SFWDTPSM        51.00000   STRALPSM      120.00000
    RHS1         SLOADPSM        90.00000   SDIGGPSM      220.00000
BOUNDS
 FX BOUNDSS1     PFWDTRIZ         5.00000
 FX BOUNDSS1     PTRALRIZ        67.00000
 FX BOUNDSS1     PLOADRIZ       154.00000
 FX BOUNDSS1     PDIGGRIZ       100.00000
 UP BOUNDSS1     PFWDTRPA        50.00000
 UP BOUNDSS1     PTRALRPA       188.00000
 UP BOUNDSS1     PLOADRPA       124.00000
 UP BOUNDSS1     PDIGGRPA       251.00000
 FX BOUNDSS1     DHTRTTNA        23.00000
 FX BOUNDSS1     DWELDGNA       106.00000
 FX BOUNDSS1     DASSLYNA        45.00000
 UP BOUNDSS1     PFWDTRPB        55.00000
 UP BOUNDSS1     PTRALRPB       210.00000
 UP BOUNDSS1     PLOADRPB       136.00000
 UP BOUNDSS1     PDIGGRPB       286.00000
 UP BOUNDSS1     DHTRTTNB        30.00000
 UP BOUNDSS1     DWELDGNB       135.00000
 UP BOUNDSS1     DASSLYNB        55.00000
 UP BOUNDSS1     PFWDTRPC        50.00000
 UP BOUNDSS1     PTRALRPC       188.00000
 UP BOUNDSS1     PLOADRPC       124.00000
 UP BOUNDSS1     PDIGGRPC       251.00000
 UP BOUNDSS1     DHTRTTNC        30.00000
 UP BOUNDSS1     DWELDGNC       135.00000
 UP BOUNDSS1     DASSLYNC        55.00000
 UP BOUNDSS1     PFWDTRPD        50.00000
 UP BOUNDSS1     PTRALRPD       188.00000
 UP BOUNDSS1     PLOADRPD       124.00000
 UP BOUNDSS1     PDIGGRPD       251.00000
 UP BOUNDSS1     DHTRTTND        30.00000
 UP BOUNDSS1     DWELDGND       135.00000
 UP BOUNDSS1     DASSLYND        55.00000
 FX BOUNDSS1     PFWDTRPE          .
 FX BOUNDSS1     PTRALRPE          .
 FX BOUNDSS1     PLOADRPE          .
 FX BOUNDSS1     PDIGGRPE          .
```

FACTORY STRIKE IN MARCH

UP	BOUNDSS1	DHTRTTNE	30.00000
UP	BOUNDSS1	DWELDGNE	135.00000
UP	BOUNDSS1	DASSLYNE	55.00000
UP	BOUNDSS1	PFWDTRPF	47.00000
UP	BOUNDSS1	PTRALRPF	180.00000
UP	BOUNDSS1	PLOADRPF	118.00000
UP	BOUNDSS1	PDIGGRPF	249.00000
UP	BOUNDSS1	DHTRTTNF	30.00000
UP	BOUNDSS1	DWELDGNF	135.00000
UP	BOUNDSS1	DASSLYNF	55.00000
UP	BOUNDSS1	PFWDTRPG	50.00000
UP	BOUNDSS1	PTRALRPG	188.00000
UP	BOUNDSS1	PLOADRPG	124.00000
UP	BOUNDSS1	PDIGGRPG	251.00000
UP	BOUNDSS1	DHTRTTNG	30.00000
UP	BOUNDSS1	DWELDGNG	135.00000
UP	BOUNDSS1	DASSLYNG	55.00000
UP	BOUNDSS1	PFWDTRPH	50.00000
UP	BOUNDSS1	PTRALRPH	188.00000
UP	BOUNDSS1	PLOADRPH	124.00000
UP	BOUNDSS1	PDIGGRPH	251.00000
UP	BOUNDSS1	DHTRTTNH	30.00000
UP	BOUNDSS1	DWELDGNH	135.00000
UP	BOUNDSS1	DASSLYNH	55.00000
UP	BOUNDSS1	PFWDTRPI	37.00000
UP	BOUNDSS1	PTRALRPI	142.00000
UP	BOUNDSS1	PLOADRPI	93.00000
UP	BOUNDSS1	PDIGGRPI	195.00000
UP	BOUNDSS1	DHTRTTNI	30.00000
UP	BOUNDSS1	DWELDGNI	135.00000
UP	BOUNDSS1	DASSLYNI	55.00000
UP	BOUNDSS1	PFWDTRPJ	37.00000
UP	BOUNDSS1	PTRALRPJ	142.00000
UP	BOUNDSS1	PLOADRPJ	93.00000
UP	BOUNDSS1	PDIGGRPJ	195.00000
UP	BOUNDSS1	DHTRTTNJ	30.00000
UP	BOUNDSS1	DWELDGNJ	135.00000
UP	BOUNDSS1	DASSLYNJ	55.00000
UP	BOUNDSS1	PFWDTRPK	60.00000
UP	BOUNDSS1	PTRALRPK	225.00000
UP	BOUNDSS1	PLOADRPK	150.00000
UP	BOUNDSS1	PDIGGRPK	312.00000
UP	BOUNDSS1	DHTRTTNK	30.00000
UP	BOUNDSS1	DWELDGNK	135.00000
UP	BOUNDSS1	DASSLYNK	55.00000
UP	BOUNDSS1	PFWDTRPL	50.00000
UP	BOUNDSS1	PTRALRPL	188.00000
UP	BOUNDSS1	PLOADRPL	124.00000
UP	BOUNDSS1	PDIGGRPL	251.00000
UP	BOUNDSS1	DHTRTTNL	30.00000
UP	BOUNDSS1	DWELDGNL	135.00000
UP	BOUNDSS1	DASSLYNL	55.00000
UP	BOUNDSS1	PFWDTRPM	50.00000
UP	BOUNDSS1	PTRALRPM	188.00000

FACTORY STRIKE IN MARCH

```
 UP BOUNDSS1   PLOADRPM      124.00000
 UP BOUNDSS1   PDIGGRPM      251.00000
 LO BOUNDSS1   PFWDTRIM       10.00000
 LO BOUNDSS1   PTRALRIM       80.00000
 LO BOUNDSS1   PLOADRIM       40.00000
 LO BOUNDSS1   PDIGGRIM       92.00000
 UP BOUNDSS1   DHTRTTNM       30.00000
 UP BOUNDSS1   DWELDGNM      135.00000
 UP BOUNDSS1   DASSLYNM       55.00000
ENDATA
```

3. REPORT PROGRAM LISTING

The following pages contain a listing of the program which accesses MPS/360 results and calculates and prints the one-page summary. For details of the programming language, reference should be made to the IBM manual for MPSRG.

FACTORY STRIKE IN MARCH

ANALYZE MDREPORT

TIME = 0.02

```
M1
N N,OVT=N,OVT+X1DFFFFFFF*C1DFFFFFFF
M1
M2
E1 11FFFFFXF
E1 11FFFFFZF
M2
M3
E2 11HTRTTF
E2 11WELDGF
E2 11ASSLYF
I N,OVT
N N,SUM=N,SUM+N,OVT
N N,OVT=E,0
M3
M5
N N,HLD=N,HLD+X1PFFFFRIF*C1PFFFFRIF
M5
M6
E5 11FWDTF
E5 11TRALF
E5 11LOADF
E5 11DIGGF
E5 11BUCKF
I N,HLD
N N,SUM=N,SUM+N,HLD
N N,HLD=E,0
M6
M8
N N,HLD=N,HLD+X1PFFFFRIF*K1FFFFI
M8
M9
E8 11FWDTF
E8 11TRALF
E8 11LOADF
E8 11DIGGF
E8 11BUCKF
I N,HLD/E,1000
N N,SUM=N,SUM+N,HLD/E,1000
N N,HLD=E,0
M9
MA
N N2COSTF=N2CCSTF+X1PFFFFRPF*C1PFFFFRPF+X1PFFFFRIF*C1PFFFFRIF
MA
MB
N N1COSTF=E,0
EA 11FWDTF & 21F
EA 11TRALF & 21F
EA 11LOADF & 21F
EA 11DIGGF & 21F
```

FACTORY STRIKE IN MARCH

```
EA 11BUCKF & 21F
ED 11HTRTTF & 21F
ED 11WELDGF & 21F
ED 11ASSLYF & 21F
N N,HLD=N1COSTF/E,1000
N N1COSTF=F,INT(N,HLD)
N N,TCOST=N,TCOST+N1COSTF
MB
MC
N N2COSTF=N2COSTF+X1DFFFFFFF*C1DFFFFFFF
MC
MD
EC 11FFFFFNF & 22F
EC 11FFFFFXF & 22F
EC 11FFFFFZF & 22F
EC 11FFFFFSF & 22F
EC 11FFFFFUF & 22F
EC 11FFFFFDF & 22F
MD
ME
N N2REVF=N2REVF+X1MFFFFRPF*C1MFFFFRPF
ME
MF
N N1REVF=E,0
EE 11FWDTF & 21F
EE 11TRALF & 21F
EE 11LOADF & 21F
EE 11DIGGF & 21F
EE 11BUCKF & 21F
N N,HLD=N1REVF/E,1000
N N1REVF=F,INT(N,HLD)
N N,TREV=N,TREV+N1REVF
MF
MG
I N1REVF+N1COSTF
MG
MH
I N1REVF
MH
MI
I N1COSTF
MI
MJ
N N,LOST=(T1SFFFFPSF-X1MFFFFRPF)*C1MFFFFRPF+N,LOST
MJ
MK
EJ 11FWDTF
EJ 11TRALF
EJ 11LOADF
EJ 11DIGGF
EJ 11BUCKF
I-N,LOST
N N,SUM=N,SUM+N,LOST
N N,LOST=E,0
```

REPORT PROGRAM LISTING

FACTORY STRIKE IN MARCH

```
  MK
  N N,TCOST=E,0
  EB 1,A
  EB 1,B
  EB 1,C
  EB 1,D
  EB 1,E
  EB 1,F
  EB 1,G
  EB 1,H
  EB 1,I
  EB 1,J
  EB 1,K
  EB 1,L
  N N,TREV=E,0
  EF 1,A
  EF 1,B
  EF 1,C
  EF 1,D
  EF 1,E
  EF 1,F
  EF 1,G
  EF 1,H
  EF 1,I
  EF 1,J
  EF 1,K
  EF 1,L
 1H                                                                      REPORT F
  C OR M.D.
  D A,POLICY='FACTORY STRIKE IN MARCH'
  D A,FORECAST='24/05/71' & A,PERIOD='FRCM NOV ''71 TO OCT ''72' & A,RUN=
  C '06/06/71'
  H MANAGEMENT POLICY:**********************************
  C                                  DATE OF . SALES FORECAST:********
  I A,POLICY
  I A,FORECAST
 2H PLANNING PERIOD  :**********************
  C                                           . CCMPLTER RUN  :********
  I A,PERIOD
  I A,RUN
  D K,DA=20&K,DB=22&K,DC=20&K,DD=20&K,DE=24&K,DF=19&K,DG=20&K,DH=20&K,DI=
  C 15&K,DJ=15&K,DK=24&K,DL=20&K,DM=239
 3H             DAYS      **      **      **      **      **      **
  C     **      **      **      **      **      **      ***
  I K,DA
  I K,DB
  I K,DC
  I K,DD
  I K,DE
  I K,DF
  I K,DG
  I K,DH
  I K,DI
  I K,DJ
```

REPORT PROGRAM LISTING

FACTORY STRIKE IN MARCH

```
I K,DK
I K,DL
I K,DM
D A,MA='NOV'&A,MB='DEC'&A,MC='JAN'&A,MD='FEB'&A,ME='MAR'&A,MF='APR'&A,M
C G='MAY'&A,MH='JUN'&A,MI='JUL'&A,MJ='AUG'&A,MK='SEP'&A,ML='OCT'
H                    MONTH     ***     ***     ***     ***     ***     ***
C    ***     ***     ***     ***     ***     *** XX   TOTAL   XX
I A,MA
I A,MB
I A,MC
I A,MD
I A,ME
I A,MF
I A,MG
I A,MH
I A,MI
I A,MJ
I A,MK
I A,ML
H ______________________|_______|_______|_______|_______|_______|_______
C |_______|_______|_______|_______|_______|_______XXXXXXXXXXXXXXX
H                       |       |       |       |       |       |
C |       |       |       |       |       |       XX      -      XX
H FINANCIAL SUMMARY     |       |       |       |       |       |
C |       |       |       |       |       |       XX   F'000   XX
H                       |       |       |       |       |       |
C |       |       |       |       |       |       XX             XX
H   REVENUE             |  **** |  **** |  **** |  **** |  **** |  ****
C |  **** |  **** |  **** |  **** |  **** |  **** XX   *****   XX
EH 1,A
EH 1,B
EH 1,C
EH 1,D
EH 1,E
EH 1,F
EH 1,G
EH 1,H
EH 1,I
EH 1,J
EH 1,K
EH 1,L
I N,TREV
H                       |       |       |       |       |       |
C |       |       |       |       |       |       XX             XX
H   COST                |  **** |  **** |  **** |  **** |  **** |  ****
C |  **** |  **** |  **** |  **** |  **** |  **** XX   *****   XX
EI 1,A
EI 1,B
EI 1,C
EI 1,D
EI 1,E
EI 1,F
EI 1,G
EI 1,H
```

REPORT PROGRAM LISTING

FACTORY STRIKE IN MARCH

```
EI 1,I
EI 1,J
EI 1,K
EI 1,L
I N,TCOST
H                                   |         |         |         |         |         |
C |         |         |         |         |         |         XX                XX
H   CONTRIBUTION                    |   *** |    *** |    *** |    *** |    *** |    ***
C |   *** |    *** |    *** |    *** |    *** |    *** XX      ****      XX
EG 1,A
EG 1,B
EG 1,C
EG 1,D
EG 1,E
EG 1,F
EG 1,G
EG 1,H
EG 1,I
EG 1,J
EG 1,K
EG 1,L
I N,TREV+N,TCOST
H                                   |         |         |         |         |         |
C |         |         |         |         |         |         XX                XX
H   F.M.I.                          |  **** |   **** |   **** |   **** |   **** |   ****
C |  **** |   **** |   **** |   **** |   **** |   **** XX     *****     XX
D K,FWDTI=2389.4&K,TRALI=207.4&K,LOADI=207.4&K,DIGGI=635.1
D K,BUCKI=52.4
N N,HLD=E,0
N N,SUM=E,0
E9 1,A
E9 1,B
E9 1,C
E9 1,D
E9 1,E
E9 1,F
E9 1,G
E9 1,H
E9 1,I
E9 1,J
E9 1,K
E9 1,L
I N,SUM/E,12
H                                   |-------|-------|-------|-------|-------|-------
C |-------|-------|-------|-------|-------|-------XX----------XX
H                                   |         |         |         |         |         |
C |         |         |         |         |         |         XX      F         XX
H   OVTM PREMIUM                    |  **** |   **** |   **** |   **** |   **** |   ****
C |  **** |   **** |   **** |   **** |   **** |   **** XX     *****     XX
N N,SUM=E,0
N N,OVT=E,0
E3 1,A
E3 1,B
E3 1,C
```

FACTORY STRIKE IN MARCH

```
E3 1,D
E3 1,E
E3 1,F
E3 1,G
E3 1,H
E3 1,I
E3 1,J
E3 1,K
E3 1,L
I N,SUM
N N,SUM=E,0
H                      |       |       |       |       |       |
C |       |       |       |       |       |       XX           XX
H    SUBCON PREMIUM    | ***** | ***** | ***** | ***** | ***** | *****
C | ***** | ***** | ***** | ***** | ***** | ***** XX   *****   XX
ML
N N,HLD=N,HLD+X1DFFFFFSF*C1DFFFFFSF
ML
MM
EL 11HTRTTF
EL 11WELDGF
EL 11ASSLYF
N N,SUM=N,SUM+N,HLD
I N,HLD
N N,HLD=E,0
MM
N N,HLD=E,0
EM 1,A
EM 1,B
EM 1,C
EM 1,D
EM 1,E
EM 1,F
EM 1,G
EM 1,H
EM 1,I
EM 1,J
EM 1,K
EM 1,L
I N,SUM
N N,SUM=E,0
H                      |       |       |       |       |       |
C |       |       |       |       |       |       XX           XX
H    F.M.I. HLDG       |  **** |  **** |  **** |  **** |  **** |  ****
C |  **** |  **** |  **** |  **** |  **** |  **** XX   *****   XX
N N,HLD=E,0
E6 1,A
E6 1,B
E6 1,C
E6 1,D
E6 1,E
E6 1,F
E6 1,G
E6 1,H
```

REPORT PROGRAM LISTING

FACTORY STRIKE IN MARCH

```
E6 1,I
E6 1,J
E6 1,K
E6 1,L
I N,SUM
N N,SUM=E,0
N N,HLD=E,0
H                                            |        |        |        |        |        |
C |        |        |        |        |        |        XX              XX
H    LOST SALES REV     | ***** | ***** | ***** | ***** | ***** | *****
C | ***** | ***** | ***** | ***** | ***** | ***** XX  ******   XX
N N,LOST=E,0
EK 1,A
EK 1,B
EK 1,C
EK 1,D
EK 1,E
EK 1,F
EK 1,G
EK 1,H
EK 1,I
EK 1,J
EK 1,K
EK 1,L
I-N,SUM
N N,SUM=E,0
H ______________________|_______|_______|_______|_______|_______|______
C |_______|_______|_______|_______|_______|_______XXXXXXXXXXXXXXX
2H -------------------------------------------------------------------
C -----------------------------------------------XXXXXXXXXXXXXXX
H                                            |        |        |        |        |        |
C |        |        |        |        |        |        XX              XX
H ACTIVITY SUMMARY                    |        |        |        |        |        |
C |        |        |        |        |        |        XX  HRS'000  XX
H                                            |        |        |        |        |        |
C |        |        |        |        |        |        XX              XX
H   STANDARD HOURS      |  **** |  **** |  **** |  **** |  **** |  ****
C |  **** |  **** |  **** |  **** |  **** |  **** XX   *****    XX
D K,FWDTH=300.39&K,TRALH=136.13&K,LOADH=114.78&K,DIGGH=226.44
D K,BUCKH=51.97
M4
N N2COSTF=N2COSTF+X1PFFFFRPF*K1FFFFH
M4
M7
N N1COSTF=E,0
E4 11FWDTF & 21F
E4 11TRALF & 21F
E4 11LOADF & 21F
E4 11DIGGF & 21F
E4 11BUCKF & 21F
N N,HLD=N1COSTF/E,1000
N N1COSTF=F,INT(N,HLD)
I N1COSTF
N N,SUM=N,SUM+N1COSTF
```

FACTORY STRIKE IN MARCH

```
M7
N N,SUM=E,0
E7 1,A
E7 1,B
E7 1,C
E7 1,D
E7 1,E
E7 1,F
E7 1,G
E7 1,H
E7 1,I
E7 1,J
E7 1,K
E7 1,L
I N,SUM
N N,SUM=E,0
H                       |       |       |       |       |       |
C |       |       |       |       |       |       XX           XX
H      MADE IN          |  **** |  **** |  **** |  **** |  **** |  ****
C |  **** |  **** |  **** |  **** |  **** |  **** XX   *****   XX
MN
N N,OVT=N,OVT+X1DFFFFFSF*K1FFFFFP*K2HRSAVNF
MN
MO
EN 11HTRTTF & 21F
EN 11WELDGF & 21F
EN 11ASSLYF & 21F
N N,HLD=N,OVT/E,1000
N N,OVT=F,INT(N,HLD)
N N,HLD=N1COSTF-N,OVT
N N,SUM=N,SUM+N,HLD
I N,HLD
N N,OVT=E,0
MO
D K,HTRTTP=2.07&K,WELDGP=2.20&K,ASSLYP=2.55
D K,HRSAVNA=160&K,HRSAVNB=176&K,HRSAVNC=160&K,HRSAVND=160&K,HRSAVNE=192
C &K,HRSAVNF=152&K,HRSAVNG=160&K,HRSAVNH=160&K,HRSAVNI=120&K,HRSAVNJ=12
C 0&K,HRSAVNK=191&K,HRSAVNL=160
N N,SUM=E,0
N N,OVT=E,0
E0 1,A
E0 1,B
E0 1,C
E0 1,D
E0 1,E
E0 1,F
E0 1,G
E0 1,H
E0 1,I
E0 1,J
E0 1,K
E0 1,L
I N,SUM
N N,SUM=E,0
```

FACTORY STRIKE IN MARCH

```
N N,OVT=E,0
N N,HLD=E,0
H                            |       |       |       |       |       |
C |       |       |       |       |       |       XX            XX
H      SUBCONTRACTED      |  ****  |  ****  |  ****  |  ****  |  ****  |  ****
C |  ****  |  ****  |  ****  |  ****  |  ****  |  ****  XX  *****  XX
MP
EN 11HTRTTF & 21F
EN 11WELDGF & 21F
EN 11ASSLYF & 21F
N N,HLD=N,OVT/E,1000
N N,OVT=F,INT(N,HLD)
I N,OVT
N N,SUM=N,SUM+N,OVT
N N,OVT=E,0
MP
N N,OVT=E,0
N N,SUM=E,0
EP 1,A
EP 1,B
EP 1,C
EP 1,D
EP 1,E
EP 1,F
EP 1,G
EP 1,H
EP 1,I
EP 1,J
EP 1,K
EP 1,L
I N,SUM
N N,SUM=E,0
H                            |       |       |       |       |       |
C |       |       |       |       |       |       XX            XX
H    MANPOWER (DIRECT)    |  ****  |  ****  |  ****  |  ****  |  ****  |  ****
C |  ****  |  ****  |  ****  |  ****  |  ****  |  ****  XX  *****  XX
MQ
N N,OVT=N,OVT+X1DFFFFFNF
MQ
MR
EQ 11HTRTTF
EQ 11WELDGF
EQ 11ASSLYF
I N,OVT
N N,SUM=N,SUM+N,OVT
N N,OVT=E,0
MR
N N,OVT=E,0
ER 1,A
ER 1,B
ER 1,C
ER 1,D
ER 1,E
ER 1,F
```

FACTORY STRIKE IN MARCH

```
ER 1,G
ER 1,H
ER 1,I
ER 1,J
ER 1,K
ER 1,L
I N,SUM/E,12
N N,SUM=E,0
H                                 |        |        |        |        |        |
C |        |        |        |        |        |                  XX              XX
H   OVERTIME - HOURS          | ***** | ***** | ***** | ***** | ***** | *****
C | ***** | ***** | ***** | ***** | ***** | ***** XX   ******       XX
MS
N N2COSTF=N2CCSTF+X1DFFFFFFF*K3HRSAVFF
MS
MT
ES 11FFFFFFXF & 22F & 32XF
ES 11FFFFFFZF & 22F & 32ZF
MT
MU
N N1COSTF=E,0
ET 11HTRTTF & 21F
ET 11WELDGF & 21F
ET 11ASSLYF & 21F
I N1COSTF
N N,SUM=N,SUM+N1COSTF
MU
D K,HRSAVZA=9.6&K,HRSAVZB=10.6&K,HRSAVZC=9.6&K,HRSAVZD=9.6&K,HRSAVZE=11
C .5&K,HRSAVZF=9.1&K,HRSAVZG=9.6&K,HRSAVZH=9.6&K,HRSAVZI=7.2&K,HRSAVZJ=
C 7.2&K,HRSAVZK=11.5&K,HRSAVZL=9.6
D K,HRSAVXA=28&K,HRSAVXB=31&K,HRSAVXC=28&K,HRSAVXD=28&K,HRSAVXE=34&K,HR
C SAVXF=27&K,HRSAVXG=28&K,HRSAVXH=28&K,HRSAVXI=21&K,HRSAVXJ=21&K,HRSAVX
C K=33&K,HRSAVXL=28
N N,SUM=E,0
EU 1,A
EU 1,B
EU 1,C
EU 1,D
EU 1,E
EU 1,F
EU 1,G
EU 1,H
EU 1,I
EU 1,J
EU 1,K
EU 1,L
I N,SUM
N N,SUM=E,0
H                                 |        |        |        |        |        |
C |        |        |        |        |        |                  XX              XX
H              - PERCENT | **.** | **.** | **.** | **.** | **.** | **.**
C | **.** | **.** | **.** | **.** | **.** | **.** XX   **.**      XX
MV
N N,OVT=N,OVT+X1DFFFFFNF*K2HRSAVNF
```

REPORT PROGRAM LISTING

FACTORY STRIKE IN MARCH

```
MV
MX
EV 11HTRTTF & 21F
EV 11WELDGF & 21F
EV 11ASSLYF & 21F
N N,HLD=(N1CCSTF/N,OVT)*E,100
I N,HLD
N N,SUM=N,SUM+N,HLD
N N,OVT=E,0
MX
N N,SUM=E,0
EX 1,A
EX 1,B
EX 1,C
EX 1,D
EX 1,E
EX 1,F
EX 1,G
EX 1,H
EX 1,I
EX 1,J
EX 1,K
EX 1,L
I N,SUM/E,12
N N,SUM=E,0
N N,OVT=E,0
N N,HLD=E,0
H _____________________|_______|_______|_______|_______|_______|_______
C |_______|_______|_______|_______|_______|_______XXXXXXXXXXXXXXX
2H -----------------------------------------------------------------------
C ------------------------------------------------XXXXXXXXXXXXXXX
H SALES SUMMARY - %    |       |       |       |       |       |
C |       |       |       |       |       |       XX     %      XX
M1
I N,OVT=(X1MFFFFRPF*C1MFFFFRPF)/(N2REVF*E,10)
N N,SUM=N,SUM+N,OVT
M1
M2
H  2FFFFFF             | **.** | **.** | **.** | **.** | **.** | **.**
C | **.** | **.** | **.** | **.** | **.** | **.** XX   **.**   XX
E1 11FFFFA & 2,A
E1 11FFFFB & 2,B
E1 11FFFFC & 2,C
E1 11FFFFD & 2,D
E1 11FFFFE & 2,E
E1 11FFFFF & 2,F
E1 11FFFFG & 2,G
E1 11FFFFH & 2,H
E1 11FFFFI & 2,I
E1 11FFFFJ & 2,J
E1 11FFFFK & 2,K
E1 11FFFFL & 2,L
I N,SUM/E,12
N N,SUM=E,0
```

```
         FACTORY STRIKE IN MARCH

M2
E2 1,FWDT & 2,FWDT
E2 1,TRAL & 2,DRILL
E2 1,LOAD & 2,LOADER
E2 1,DIGG & 2,DIGGER
H ____________________|_______|_______|_______|_______|_______|_______
C |_______|_______|_______|_______|_______|_______XXXXXXXXXXXXXXX

 NO ERRORS - ESTIMATE OF NUMBER OF BYTES REQUIRED ON REPORT AND SCRATCH
```

9. BIBLIOGRAPHY

9.1. Referenced in the Text

FINANCE

Brown, J. L. & Owler, L. W. J.: Wheldons Cost Accounting and Costing Methods

Horngren, C. T.: Cost Accounting

National Association of Accountants: Research Report 43 - Financial Analysis to Guide Capital Expenditure Decisions

Quirin, G. D.: The Capital Expenditure Decision

Solomon, E.: The Theory of Financial Management

Shillinglaw, G.: Cost Accounting

L.P.

Beale, E. M. L.: Mathematical Programming in Practice

Dantzig, G. B. : Linear Programming & Extensions

Driebeek, N. J. : Applied Linear Programming

Elmaghraby, S. E. & Cole, R. T. : On the Control of Production in Small Job Shops. Journal of Industrial Engineering, Vol. 14, 1963, pp. 186-196

Gass, S. I. : Linear Programming. Methods & Applications

Hanssman, F. : Operations Research in Production & Inventory Control

Hillier, F. S. & Lieberman, G. I. : Introduction to Operations Research

Teichroew, D. : An Introduction to Management Science

Wagner, H. M. : Principles of Management Science

PLANNING

Ackoff, R. L. : A Concept of Corporate Planning

Argenti, J. : Corporate Planning - A Practical Guide

Ewing, D. W. : The Practice of Planning

Newman, W. H. & Logan, J. P. : Business Policies and Central Management

Steiner, G. A. : Top Management Planning

Steiner, G. A. & Cannon, W. M. : Multinational Corporate Planning

PRODUCTION

Burbidge, J. L. : The Principles of Production Control

Bowman, E. H. & Fetter, R. B. : Analysis for Production Management

Buffa, E. L. : Readings in Production & Operations Management

Magee, J. F. : Production Planning & Inventory Control

Moore, F. G. : Production Control

GENERAL

Bower, J. L. : Managing the Resource Allocation Process

Cyert, R. M. & March, J. G. : A Behavioural Theory of the Firm

Mao, J. C. T. : Quantitative Analysis of Financial Decisions

Gershefski, G. W. : Building a Corporate Financial Model. H.B.R., July-August 1969

Goldie, J. H. : Simulation and Irritation. Corporate Simulation Models by Schrieber, A. N.

9.2. IBM Manuals

MPS/360 Manuals

To run MPS/360:

. Control Language User's Manual	H20-0290
. Linear & Separable Programming User's Manual	H20-0476
. Message Manual	H20-0603

To write Reports:

. Application Description	H20-0136
. Report Generator (MPSRG) Program Description Manual	GH20-0560
. Version 2 Read Communications Format (READCOMM) Program Reference Manual	H20 0372
. Basic Fortran IV Language (OS Manual)	C28-6629

To prepare MPS/360 for use: .

. Version 2 Operations Manual	GH20-0602

To prepare MPSRG for use:

. Report Generator (MPSRG) Operations Manual	H20-0561

OS/360 Manuals

Dataset Management:

. Job Control Language Reference	GC28-6704
. J. C. L. Charts	N28-2382
. Utilities	GC28-6586

To operate the computer:

. Operating System; Operator's Procedures	GC28-6692
. Operator's Reference	GC28-6691
. Messages and Codes	GC28-6631

9.3. General References

Ackoff, R. L. : Progress in Operations Research

Ansoff, H. I. : Corporate Strategy

Anthony, R. N. : Planning and Control Systems : A Framework for Analysis

Anthony, R. N., Dearden, J., Vancil, R. F. : Management Control Systems

Arrow, K. J., Karlin, S., Scarf, H. : Studies in the Mathematical Theory of Inventory and Production

Babcok, G. C. : The Concept of Sustainable Growth. Financial Analysts Journal, May-June 1970

Bowman, E. H. : Assembly Line Balancing by L.P. Op. Res., No. 8, 3rd May, 1960, p.385

Bowman, E. H. : The Schedule Sequencing Problem, in Op. Res., No. 7, 5th September, 1959, p.621

Bowman, E. H., Fetter, R. B. : Analysis for Production Management

Buffa, E. S. : Models for Production and Operations Management

Buffa, E. S. : Readings in Production and Operations Management

Chambers, D. : An Approach to Capital Budgeting. European Business, May 1967

Chandler, A. D. : Strategy and Structure

Conway, R. W. : Theory of Scheduling

Dantzig, G. B., Wolfe, P. : The Decomposition Algorithm for L.P. Econometrica 29, No. 4, and Op. Res. 8 January 1960, p.101

Denning, B. W. : Corporate Planning - Selected Concepts

Elmaghraby, S. E. : The Design of Production Systems

Fetter, R. B. : An L.P. Model for Long-Range Capacity Planning. Management Science 7, No. 4, 1961

Fogler, H. R. : Ranking Techniques and Capital Budgeting. The Accounting Review, January 1972

Forrester, J. W. : Industrial Dynamics

Garvin, W. W. : Linear Programming

Gershefski, G. W., Harvey, A. : Corporate Models. The State of the Art. Management Science, Vol. 16, No. 6, 1970

Gilmore, F. F. Brandenburg, R. G. : Anatomy of Corporate Planning. H.B.R., November-December 1962

Glueck, W. F. : Organization Planning and Development

Granger, C. H. : The Hierarchy of Objectives. H.B.R., May-June 1964

Hadley, E. O., Candler, W. : Linear Programming Methods

Hadley, G. : Linear Programming

Hadley, G. : Nonlinear and Dynamic Programming

Hansmann, F., Hess, S. W. : An L.P. Approach to Production and Employment Scheduling. Management Technology, January 1960

Harrison, J. O. : L.P. and Operations Research. Operations Research for Management by McLoskey, J. R. and Trefethen, F. N.

Henderson, A., Schlaifer, R. : Mathematical Programming, Better Information for Better Decision Making. H.B.R. May-June 1954

Holt, C. C., Modligiani, F., Simon, H. : A Linear Decision Rule for Production and Employment Scheduling. Management Science, October 1955, p.1, Management Science, January 1956, p.159

Holt, C. C., Modligiani, F., Muth, J., Simon, H. : Planning Production Inventories and Work Force

Jones, W. G., Rope, C. M. : L.P. Applied to Production Planning. Op. Res. Q, 15, No. 4., p.293, 1964

Karush, W. : On a Class of Minimum Cost Problems. Management Science 4, p.136-155

Klein, M. : Production Smoothing. Management Science 7, P.286

Koenigsberg, E. : Some Industrial Applications of L.P. Op. Res. Q., 12, No. 2, 1961

Levin, R. I., Lamone, R. P. : Linear Programming for Management Decisions

Livingstone, J. L. : Management Planning and Control

Mansfield, E. : Managerial Economics and Operations Research

McCloskey, J. F., Trefethen, F. N. : Operations Research for Management

McGarrah, R. E. : Production and Logistics Management

McKenney, J. L. : The Roles of Simulation Models in Planning. Corporate Simulation Models by Schreiber, A. N.

McLean, J. G. : How to Evaluate New Capital Investments. H.B.R., November-December 1958

McMillan, C., Gonzalez, R. F. : Systems Analysis. A Computer Approach to Decision Models

McNeill, G., Miller, M. : Inputs to Corporate Planning: Forecasting the External Environment. Industrial Marketing Management 2 (1972)

McRae, T. W. : Analytical Management

Merrett, A. J., Sykes, A. : The Finance and Analysis of Capital Projects

Miller, E. C. : Advanced Techniques for Strategic Planning

Modligiani, F., Hohn, F. E. : Production Planning Over Time and the Nature of Expectations and the Planning Horizon. Econometrica 23, p.46-66, 1955

Optner, S. L. : Systems Analysis

Rudwick, B. H. : Systems Analysis for Effective Planning

Sasieni, M., Yaspan, A., Freidman, L. : Operations Research

Schild, A. : On Inventory Production and Employment Scheduling. Management Science 5, p.157-168

Simon, H., Holt, C. C., Modligiani, F. : Controlling Inventory and Production In Face of Uncertain Sales. National Convention Transactions. American Society for Quality Control, p.371, 1956

Teichroew, D. : An Introduction to Management Science

Varzsonyi, A. : Scientific Programming in Business and Industry

Wagle, B. : Corporate Models in Planning. Journal of European Business, 15, p.9-17

Wagle, B. : The Use of Models for Environmental Forecasting and Corporate Planning. Op. Res. Q, Vol. 20, No. 3

Weingartner, H. M. : Mathematical Programming and the Analysis of Capital Budgeting Problems

Whitin, T. M. : The Theory of Inventory Management

Whittle, P. : Optimization Under Constraints

Williams, N. : Linear and Nonlinear Programming in Industry